AD-A114 028 RAND CORP SANTA MONICA CA F/G 15/5

CARRIER BASED AIR LOGISTICS STUDY: MAINTENANCE ANALYSIS.(U)

JAN 82 T F LIPPIATT, L B EMBRY, J SCHANK N00014-80-C-0049

UNCLASSIFIED RAND/N-1784-NAVY NL

1 OF 2

AD A 114028

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(12)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER N-1784-NAVY	2. GOVT ACCESSION NO. AD-A114028	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Carrier Based Air Logistics Study: Maintenance Analysis		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) T. F. Lippiatt, L. B. Embry, J. Schank		8. CONTRACT OR GRANT NUMBER(s) N00014-80-C-0049
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Rand Corporation 1700 Main Street Santa Monica, CA. 90406		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Navy		12. REPORT DATE January 1982
		13. NUMBER OF PAGES 125
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

No Restrictions

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Logistics Support
Logistics Management
Supply Management
Logistics Operations
Repair Shops
Aircraft Carriers

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See Reverse Side

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

The Carrier Based Air Logistics (CABAL) study examined alternative logistics policies and structures for support of avionics equipments installed on six aircraft in most carrier deckloads--the E-2C, F-14A, S-3A, and three A-6 variants. It considered the entire logistics support system for component repair and the interaction of its various elements, including maintenance, supply, and transportation. This Note documents in further detail the maintenance analysis. It focuses on three key resources employed by the logisitics support system: maintenance manpower, test equipment, and management.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

(12)

A RAND NOTE

CARRIER BASED AIR LOGISTICS STUDY:
MAINTENANCE ANALYSIS

T. F. Lippiatt, L. B. Embry,
J. Schank

January 1982

N-1784-NAVY

Prepared For The Department of the Navy

Rand
SANTA MONICA, CA. 90406

PREFACE

The Carrier Based Air Logistics (CABAL) study has two primary purposes: (1) to evaluate a specific alternative to the current logistics support structure suggested for further analysis in the Defense Resource Management Study (DRMS) report to the Secretary of Defense (February 1979) and (2) to identify and evaluate potential improvements in the current logistics support structure that could enhance aircraft availability during wartime without the complete structural change required by the DRMS alternative.

The study focuses on key logistics elements that support carrier aircraft, including the supply system, shipboard component repair facilities (including test equipment), maintenance manpower for those facilities, and transportation for the resupply of components not reparable aboard ship and the return of components to be repaired at depot facilities. Changes suggested in this study are directed toward improving the readiness and availability of carrier based aircraft rather than toward reducing cost. Most recommendations suggest implementation rather than further study. In those cases that warrant further study, the Navy either is already performing such analysis or has an in-house capability for doing so.

This Note describes in detail the CABAL maintenance analysis summarized in <u>Carrier Based Air Logistics Study: Integrated Summary</u>, R-2853-NAVY. It is complemented by two companion papers that describe other aspects of the analysis:

CABAL Supply and Transportation Analysis [Ref. 3]

CABAL Data Sources and Issues [Ref. 1]

This work was sponsored by the Office of the Chief of Naval Operations (OP-51).

SUMMARY

The primary objective of the Carrier Based Air Logistics Study (CABAL) was to identify and evaluate alternative logistics support policies with respect to their potential to improve aircraft availability and performance in wartime. In doing so, the study was to consider the entire logistics support system and the interaction of its various components, including maintenance, supply, and transportation.

BACKGROUND

The Defense Resource Management Study (DRMS) [Ref. 9] included a preliminary analysis of the carrier based air logistics support as part of its investigation of logistics support alternatives for a variety of combat weapon systems. The study suggested that low peacetime aircraft availability was a major problem and identified alternative policies which might improve both peacetime readiness and wartime operational performance.

The DRMS suggested that the relatively small size of carrier squadrons (combined with existing stockage, maintenance manpower, and test equipment requirements policies) was a primary cause of the aircraft availability problem. For each carrier the logistics system has to support seven to eight different aircraft types assigned to nine to ten squadrons, each having a small number of aircraft--as few as four and as many as 12.

Small aircraft populations mean small scale in logistics operations. A number of areas were identified in which the relatively small scale, coupled with resource requirement policies, might have an adverse effect on logistics support. With a demand-based stockage policy, the quantity of on board spares is limited by the low demand generated by the small numbers of each type of aircraft, making it difficult to stock the extremely wide range of parts that could be required to repair aircraft components. This limited range of on board repair parts can result in long awaiting parts (AWP) time, thus slowing the component repair process.

Test equipment requirement policies differ from those for providing spare parts. Typically, test equipment is provided if there is demand for on board repair. Thus, the range of aircraft that must be supported determines the requirements for many different types of test equipment. Because most equipment is highly specialized and testing demands are low, test equipment utilization tends to be low. This, coupled with the demand-based stockage policy, make it difficult to stock the range of test equipment repair parts that might be required. It is also difficult to provide the necessary maintenance skills and calibration equipment because of the diverse range of equipment to be supported.

A similar problem exists in the requirements for manpower. Intermediate-level repair personnel are assigned to each squadron and the manpower requirement is based on each squadron's workload spread across numerous naval enlisted classifications (NECs). If there is a repair requirement, no matter how small the projected workload, a billet is required. Again, because of the small size of each squadron, many of these personnel have small workloads and low utilization.

Based on a limited analysis of these issues, the DRMS recommended further investigation and evaluation of a logistics support alternative that would move some intermediate-level repair from the carrier to shore-based Aviation Intermediate Maintenance Departments (AIMDs). This would increase the scale of repair by consolidating the requirements for manpower, test equipment, and repair parts at fewer locations. The hypothesis was that this would result in (1) reduced manpower requirements, the savings from which could be used to provide additional spare components on board the carrier or improved transportation, (2) reduced AWP time, and (3) improved test equipment utilization and availability. The results also suggested that a reduction in AWP and improved test equipment availability would reduce repair times.

In addition to suggesting that some of the component repair could be moved to shore-based facilities, the DRMS recommended that a more responsive transportation system be investigated since it would benefit both the shore repair alternative and the current support structure. It also recommended that utilization of manpower could be improved by cross training (creating billets with dual NECs) and by using the scale of the total AIMD workload to determine manning requirements (rather than segmenting workload by squadron and aircraft type).

CABAL STUDY OBJECTIVES

The primary objective of the CABAL study, like that of the DRMS, was to identify and examine alternative logistics support policies which would improve wartime aircraft availability and operational performance [Ref. 6]. A key task of the study was to fully evaluate the DRMS findings with more complete and more recent data. In addition to examining the DRMS recommendations, including the shore repair alternative, the CABAL study was to identify and evaluate other options which might improve the performance of the current logistics support structure. The following summarizes the findings and recommendations. They are organized by logistics system functional area followed by an integrated summary of findings concerning the DRMS shore repair alternative.

FINDINGS AND RECOMMENDATIONS

Maintenance Manpower

Research in the maintenance manpower area concentrated on utilization rates resulting from current manpower requirements methodologies, potential improvements to that methodology, the scale of shipboard AIMDs, and the implications of improvements and consolidated wartime workload for the shore repair alternative. The following briefly describes the results.

Current maintenance manpower requirements (from Ref. 8, ACM-02) are based on peacetime workloads. Increases in workload associated with acceleration of the flying program during wartime will overload many carrier avionics work centers.

A carrier manpower requirement based on the total AIMD wartime workload generated from all carrier aircraft would be no larger than the current ACM-02 requirement. The mix of skills, however, would differ significantly and would support the wartime workloads at all work centers.

No manpower savings would result from consolidating carrier workloads at shore-based AIMDs. Projected manpower utilization rates on board the carrier under the wartime AIMD manning alternative exceed 90 percent for all avionics work centers.

Based on these findings it is recommended that the Navy base manpower requirements on projected wartime AIMD workloads rather than on peacetime squadron workload. Revisions in personnel management would require Navy policy decisions. Limited analysis, however, tends to favor a policy that assigns component repair personnel directly to an AIMD rather than to individual aircraft squadrons.

Test Equipment

As in the manpower analysis, research on test equipment considered projected wartime utilization rates and possible improvements from moving some repair ashore. For example, underutilized test equipment might be better utilized ashore (creating cost savings that could be applied to other logistics support resources), and overloaded test equipment might benefit from spare capacity ashore. The following paragraphs briefly describe the results.

Versatile Automated System Test (VAST) does not have sufficient capacity to support the on board workload generated by a sustained wartime flying program. The effect of this capacity limitation is scenario-dependent. With well-managed priority repair and cannibalization, the VAST can support a wartime flying program for limited periods of time without severe degradation in aircraft availability. For longer, sustained scenarios, aircraft availability will decrease dramatically as the repair backlog increases.

Most other test equipments have low projected wartime utilization. However, no significant near term cost savings would be realized by centralization of repair because equipment in the current inventory represents a sunk cost. This does not apply to future aircraft systems being brought into the Navy Shipboard Aircraft inventory.

Based on these findings, we recommend that the Navy decide among options to reduce the projected VAST capacity shortfall. Because the magnitude of the VAST problem is scenario-dependent, careful consideration should be given to scenario assumptions before deciding on ways to reduce the VAST backlog. For example, a reduction in S-3A aircraft wartime flying from programmed rates to those rates used in computing stockage requirements would reduce the VAST workload from 160 percent to 132 percent of current shipboard capacity. One alternative to reduce the backlog would be to move all Shop Replaceable Assembly (SRA) repair to other shipboard test equipment where it is technically feasible. Another is to move it to VAST stations at shore-based facilities with excess wartime capacity. A combination of both options is likely to be the least expensive, but if all VAST SRA repair were moved ashore the cost of additional spare parts to cover the transportation pipelines would be about $600,000 per carrier at the full wartime flying program. With the reduced S-3A flying requirements and the shore repair option, the additional stockage cost would be about $450,000 per carrier, with the VAST workload reduced from 160 percent to 114 percent of capacity.

None of the alternatives discussed here bring the VAST workload down to 100 percent of capacity. To do so would require moving some Weapon Replaceable Assembly (WRA) repair off VAST in addition to all SRA repair, or buying three additional VAST stations per carrier. Any reduction in workload, however, will allow for longer periods of sustainability and therefore decisions on how much reduction is required depend heavily on the scenario to be supported.

The Navy should also <u>explicitly consider the test equipment implications of a shore-based repair option for future systems</u>. Purchasing the stock needed to fill transportation pipelines may be less expensive than buying unique, low utilization test equipments for all of the carriers. Using shore-based Intermediate Maintenance Activities (IMAs) as an option should be considered explicitly during the Level of Repair (LOR) decision process.

<u>Maintenance Management</u>

Because a remote repair location may not be as responsive to immediate needs as a shipboard AIMD, the study attempted to quantify the possible benefits of local priority repair, especially as might be obtained with good maintenance management. It was found that <u>priority repair is an extremely powerful tool that can compensate over limited time horizons for a variety of resource shortages</u>. It can, in effect, shorten repair times for critical items to maintain maximum aircraft availability in the face of short-term resource shortages. The analysis showed that the effects on performance of the VAST capacity shortfall would be severe even with priority repair. If the demand for capacity is reduced to about 110 percent of the available supply, however, priority repair can overcome potential VAST constraints on performance. The necessary demand reduction can be achieved by: (1) reducing the S-3A flying program to that used in current resource decisions and (2) moving SRA repair to other test equipments or ashore.

This analysis demonstrated that maintenance use of a scheduling rule that explicitly considers the stock position of each item repaired can concentrate repair capacity on those components most likely to degrade aircraft availability. Thus it is recommended that the Navy include support of priority repair management explicitly in its continuing development of maintenance management support systems such as NALCOMIS.

DRMS Shore Repair Alternative

The results of the maintenance analysis have been integrated with those of the supply and transportation analysis [Ref. 3] to provide a basis for evaluation of alternative logistics structures. The integrated results are reported in Ref. 5. The study findings indicate that with the exception of the wartime VAST capacity limitations and potential economies for future test equipment requirements, the DRMS shore repair alternative, in general, is not currently attractive. Implementing other DRMS recommendations to dual code NECs and to consider the total wartime AIMD workload when establishing manpower requirements would yield utilization rates exceeding 90 percent for all of the avionics work centers. Thus, no manpower savings would be generated by moving repair ashore--savings which, in turn, could be invested in additional shipboard supply stocks or improved transportation. The maintenance management analysis showed that local priority repair potentially provides the flexibility to dramatically shorten repair times for critical components and compensate for short-term resource shortages.

The supply analysis showed that additives to the AVCAL to increase the range of low demand component repair parts at a relatively low cost and SRA cannibalization significantly reduced AWP problems and that moving repair ashore to consolidate the demand for repair parts did not improve AWP delays sufficiently to offset the long transportation pipeline. There were no manpower savings to offset the additional transportation pipeline stockage costs. The supply analysis also showed that using an aircraft availability objective rather than a fill rate objective significantly improved performance without cost increases.

The test equipment analysis, on the other hand, showed that the VAST work center did not have sufficient capacity to support the workload generated by a sustained wartime flying program. One alternative to alleviate the wartime backlog would be to move, where feasible, all VAST SRA repair to other shipboard equipment. Another would be to move SRA repair to shore-based facilities with excess wartime capacity. A combination of both options is likely to be the least expensive. The test equipment analysis also showed that most test equipment had low utilization, but because the current equipment inventory represents a sunk cost, little near-term savings would be generated by consolidating repair ashore. Decisions about future system test equipment requirements should consider the shore repair option as it may be cost effective.

Therefore, based on the CABAL analysis, the shore repair alternative does not look promising for most components. It should, however, be considered in dealing with the wartime VAST backlog and future test equipment requirements. Until decisions are made about how to solve the VAST backlog, it is not recommended that the shore repair alternative be tested.

ACKNOWLEDGMENTS

The CABAL study could not have been performed without the excellent cooperation from the Navy. Admiral P. H. Speer (OP-05B) and the entire Navy Advisory Board provided useful advice and criticism which contributed to the balance and credibility of the analysis. The study benefited immensely from the many helpful comments and criticisms of Admiral R. W. Carius (OP-51) and his staff. Captain Charles Bolinger and his assistant, Lt. Commander Stanley Hunter, were instrumental in steering us to the right agencies and persons for data acquisition, orientation, and expert opinion. Without exception, Navy personnel at all levels were frank, open, and cooperative in their interactions with the CABAL study group.

We wish to thank Frank Swofford of the Navy Secretariat for his encouragement and support throughout the study. Our special thanks to our secretary, Dee Saenz, for keeping the administrative details of trips, meetings, and paperwork from completely engulfing us. Thanks also to Dee and Suzi Jackson for their support in the final documentation, and to Patricia Dey and Earl Gardner for programming support.

CONTENTS

FIGURES

TABLES

GLOSSARY

3M	Maintenance and Material Management System
AECL	Avionics Equipment Configuration List
AIMD	Aircraft Intermediate Maintenance Department
ASO	Aviation Supply Office
ASW	Antisubmarine Warfare
AVCAL	Aviation Consolidated Allowance List
AWP	Awaiting Parts
BCM	Beyond the Capability of Maintenance
CABAL	Carrier Based Air Logistics Study
CANN	Cannibalization
CATS	Computer Aided Test Set
CNA	Center for Naval Analyses
COMM	Communications
CV	Carrier
DRMS	Defense Resource Management Study
Dyna-METRIC	Dynamic Multi-Echelon Technique for Reparable Item Control
ELEC	Electrical
EXREP	Expedited Repair
FMC	Fully Mission Capable
FMCA	Fully Mission Capable for Avionics
HATS	Hybrid Automated Test Set
I-Level	Intermediate Level
IMA	Intermediate Maintenance Activities
INS	Inertial Navigation System

INST	Instruments
IO	Indian Ocean
LOR	Level of Repair
LPH	Landing Platform, Helicopter
MOD	Module
NALCOMIS	Naval Aviation Logistics Command Management Information System
NARF	Naval Air Rework Facility
NAS	Naval Air Station
NATO	North Atlantic Treaty Organization
NAVMMACLANT	Navy Manpower and Material Analysis Center, Atlantic
NAV	Navigation
NEC	Naval Enlisted Classification
NMC	Non-Mission Capable
NMCM	Non-Mission Capable--Maintenance
NMCS	Non-Mission Capable--Supply
O-Level	Organizational Level
OPDET	Operational Detachment
O&ST	Order and Ship Time
PMC	Partially Mission Capable
POE	Projected Operational Environment
RIMSTOP	Retail Inventory Management Stockage Policy
ROC	Requirement for Operational Capability
SACE	Semi-Automatic Checkout Equipment
SAF	Support Action Form
SAVAST	Ships AVCAL Asset Demand Tape

SCIR	Subsystem Capability Impact Report
SQMD	Squadron Manning Document
SRA	Shop Replaceable Assembly
TAD	Temporary Additional Duty
TYCOM	Type Commander
VAST	Versatile Avionics Shop Test
VSL	Variable Safety Level
WRA	Weapon Replaceable Assembly

I. INTRODUCTION

The Carrier Based Air Logistics (CABAL) study examined alternative logistics policies and structures for support of avionics equipments installed on six aircraft in most aircraft carrier deckloads--the E-2C, F-14A, S-3A, and three A-6 variants. It considered the entire logistics support system for component repair and the interaction of its various elements, including maintenance, supply, and transportation. Although all echelons of the support system play a role in supporting aircraft avionics, the intermediate level of support has a direct effect on aircraft availability and wartime performance capability. Hence most of the analysis of policy options centered on what has traditionally been the shipboard level of support.

BACKGROUND

The Defense Resource Management Study (DRMS) [Ref. 9] included a preliminary analysis of carrier-based air logistics support as part of an investigation of logistics support alternatives for a variety of combat weapon systems. The results suggested that low peacetime aircraft availability was a major problem and presented preliminary analyses to identify alternative policies which could improve both peacetime readiness and wartime operational performance.

A key task of the CABAL study was to evaluate the DRMS findings using more complete and more recent data. In addition to examining the DRMS recommendations, including the shore repair alternative, the CABAL study was to identify and evaluate other options which might improve the performance of the current logistics support structure [Ref 6]. If such options did show promise, they might be preferable to the shore repair alternative. This investigation was to be based on a cross-functional analysis of the interdependent elements of the logistics support system. It was also to consider the implementation issues raised by its recommendations for improving wartime aircraft availability.

This Note documents in further detail the maintenance analysis summarized in Ref. 5. It focuses on three key resources employed by the logistics support system: maintenance manpower, test equipment, and management.

THE MAINTENANCE PROCESS AND MAINTENANCE CAPACITY

Navy aircraft maintenance involves both on-equipment and off-equipment maintenance. On-equipment work is to identify and remove and replace defective components at the aircraft. Off-equipment maintenance is to repair the components removed from the aircraft. These two types of maintenance capabilities and responsibilities are distributed across three levels of maintenance:

- Organizational (O-level)
- Intermediate (I-level)
- Depot

The organizational level performs most on-equipment maintenance. After troubleshooting and isolating a defective component, the O-level mechanic removes the component and replaces it with a spare drawn from local (retail) supply. These remove and replace maintenance actions constitute demands on the logistics system.

The primary source of supply for the components installed by the organizational level is intermediate level maintenance. Most avionics Weapon Replaceable Assemblies (WRAs) are reparable; they are "black boxes" that can be repaired at a fraction of their procurement cost by replacing Shop Replaceable Assemblies (SRAs, which are themselves reparable) and/or other components. Over 80 percent of the WRAs considered in the CABAL study were restored to a serviceable condition by the carrier or Naval Air Station (NAS) Aviation Intermediate Maintenance Department (AIMD).

The 20 percent of WRAs, and 35 to 40 percent of SRAs, that are not repaired by the AIMD are evacuated to a Naval Air Rework Facility (NARF) or contractor's plant for depot-level maintenance. Components repaired at the depot level are returned to wholesale supply stocks. These stocks are used to replenish retail level inventories, or to meet organizational level maintenance demands, when repairs are Beyond the Capability of Maintenance (BCM) at the I-level.

Since the AIMD is the primary retail source of supply for reparable components, I-level maintenance is a primary determinant of both retail supply performance and aircraft operational availability. If maintenance turnaround times exceed those assumed in the development of supply stockage requirements, repair pipelines will be unbalanced. The needed items in the repair segment of the pipeline will be drawn from other available pools of stock--including, if necessary, the aircraft that the logistics system exists to support.

The critical problem for intermediate level maintenance management is to satisfy the demand for maintenance generated by O-level removals with the supply of maintenance resources. The relevant measures of capacity are maintenance manhours and test equipment hours.

The demand for maintenance is a function of the number of O-level removals and the manhours and/or test equipment hours[1] required to process each removal. Based on classic failure theory, which associates failures with equipment utilization, and empirical evidence, removals are usually assumed to vary with aircraft flying hours. Thus the demand for maintenance, which equals the sum across all items of the product of the failure rate and test time, can also be expressed as a function of flying hours. Mathematically,

$$D_{MMH,EMT} = \sum_{i=1}^{n} (\text{removals/day x service time})$$

where D = demand

MMH = maintenance manhours

EMT = elapsed maintenance time

Removals/day = (removals/flying hour) x (flying hours/day)

Service time = MMH/action or EMT/action

i = items

[1] Elapsed Maintenance Time (EMT) was used as a proxy for test equipment time in the CABAL maintenance analysis.

The average service time will be affected by the proportion of items BCM, the percentage of removals in which I-level maintenance can find nothing wrong,[2] and the probability that the repair action will be delayed while awaiting parts (AWP).[3]

The supply of maintenance is determined by the level of repair capability assigned to the AIMD by maintenance policy and the capacity of the maintenance facility, which is a function of manpower and test equipment availability. Manpower levels and utilization policies define the supply of available maintenance manhours. Current policy states that a mechanic should be available for 60 hours of productive work per week during wartime.[4] Available test equipment hours are determined by the number of equipments provided and their availability.[5]

Maintenance capacity utilization is simply the demand for maintenance in hours divided by the available supply. Because Navy policy is to provide a carrier with the resources in peacetime that will be needed to support the wartime flying program, the peacetime utilization fraction should be (and is) less than one for all skills and test equipments. The CABAL analysis identified several instances in which the wartime utilization fraction will exceed one if the postulated linear relationship between the flying program and the demand for maintenance holds true. These cases, and recommendations for mitigating their potential effects on operational performance, are discussed in this Note.

---

[2] Over 25 percent of the WRA and 30 percent of SRA removals recorded in the CABAL data base were coded A799--no defect.

[3] Service times for items that experience AWP are about 50 percent longer than for removals that can be fixed immediately.

[4] Navy manning policy assumes a shipboard wartime availability of 60 hours/man/week [Ref. 8].

[5] Test equipment availability is a function of inherent equipment reliability and the time required to repair the equipment, including AWP time.

OUTLINE OF THE NOTE

The subsequent four chapters document in detail the CABAL maintenance analysis summarized in Chapter III of the Integrated Summary [Ref. 5]. Chapter II provides an overview of the study methodology. Chapter III describes the manpower analysis and recommends changes in the way I-level maintenance manpower requirements are developed and AIMD personnel are managed. Chapter IV describes the test equipment analysis, which identified a wartime capacity constraint on the Versatile Avionics Shop Test (VAST) test stand used to repair a number of critical avionics components for the F-14A, S-3A, E-2C, and A-6E. Chapter V discusses maintenance management, with particular emphasis on the value of, and information requirements for, effectively managed priority repair. Chapter VI summarizes the findings and recommendations of the CABAL maintenance analysis.

II. METHODOLOGICAL APPROACH

The methodological approach to the CABAL study consisted of three primary tasks:

- o Scenario definition.
- o Data base development.
- o Modeling and data analysis.

This chapter gives an overview of the methodological approach to aid in understanding the analysis and the basis for the recommendations in Chapter VI.

SCENARIO DEVELOPMENT

Most Navy resource requirements methodologies reflect the assumptions of classical failure theory, which associates the failures of aircraft components with aircraft utilization expressed in flying hours. The CABAL study also assumed this linear relationship between failures (which generate maintenance workload and pipeline stockage requirements) and flying activity. It was therefore necessary to develop a scenario that would generate a flying program consistent with Navy wartime planning as a prerequisite to projection of wartime aircraft availability.

Two scenarios were considered in the modeling effort:

- o A "steady-state" program with level flying activity on each day of a 90-day period.

o A "square wave" program that assumed a 30-day Indian Ocean contingency followed by transition to a NATO war.

Both scenarios were based on data for programmed wartime flying activity obtained from the Navy.

Although the steady-state scenario does generate programmed flying hours for each of the aircraft considered in the study, it does not contain transients in flying rates that can have a significant effect on maintenance backlogs, repair generations, and supply stockage position. The second scenario, which assumes periods of standdown followed by periods with higher-than-programmed flying activity, generates the same flying hours over a 90-day period as the first but also has transients in pipeline assets.

In both cases the component removals and demands for resupply are the same when averaged across about 45 days. The primary difference is that aircraft maintain continuous activity at programmed sortie rates in the steady-state scenario, whereas the dynamic scenario has periods of high activity followed by periods of no activity. In the former case the aircraft must be maintained in a high state of readiness at all times, whereas in the latter case the availability needs vary depending on the activity rate. The ability of a set of resources to support the sustained steady-state rates means that they should also be able to support the dynamic flying rates. Conclusions from the steady-state scenario were tested in the long-term dynamic scenario.

The effects of an interruption in the resupply pipeline to the carrier were also considered for both scenarios. These excursions permitted evaluation of the protection afforded by the carrier's self-sufficiency stock under a variety of stockage policies.

The possible effects of aircraft attrition on the demand for logistics support were not considered because combat losses were assumed to be replaced by filler aircraft. Of course, if attrition reduced the total aircraft inventory to the point that filler aircraft were not available, support requirements would be reduced accordingly. In this sense, the scenario generates a conservative (high) estimate of likely demands for support.

THE CABAL DATA BASE

As is common in studies of this type, much of the study effort was devoted to development of a data base describing characteristics of the components to be considered in the analysis. The aircraft were the F-14A, the S-3A, the E-2C, and three A-6 variants in a typical deckload. Since the study was to include avionics equipments, the set of components to be considered for these aircraft was initially based on the Avionics Equipment Configuration List (AECL) for the deckload carried by the USS CONSTELLATION on her 1978 WESTPAC deployment.

When it became apparent that a component list based on the AECL did not include many of the components that generate workload in avionics work centers,[1] the data base was expanded to include these items. Demand and repair data for these components were then extracted from the Navy's 3M system, and the data base was augmented with information on test equipment and skill requirements, depot repair time, and other item characteristics from a number of different sources.

[1]That is, workload reported through the Navy's Maintenance and Material Management (3M) system showed other components being repaired in the work center.

The data describe the configuration of aircraft and components, historical removals and BCM rates, repair times including scheduling, processing, and hands-on repair durations, test equipment requirements, manhour requirements, and so forth. The 3M failure and repair data reflect fleetwide experience for the period 1 July 1978 through 30 June 1979. More recent data were available, but data reporting problems associated with implementation of the Subsystem Capability Impact Reporting (SCIR) system made these data suspect. Navy representatives thus advised use of data from the earlier period to minimize data quality problems associated with SCIR implementation.

Component-specific data, and indentured[2] relationships between components extracted from the Aviation Supply Office (ASO) weapon system file, were used for a variety of statistical analyses to describe peacetime performance of the aircraft material readiness support system. They were also used in conjunction with scenario data for the modeling efforts described below.

MODELS EMPLOYED IN THE STUDY

Two primary models[3] were used in the analysis reported here: (1) A model of the logistics support process for evaluating the effects of

[2] Indentured relationships describe the application of subcomponents to their next higher assembly, i.e., the set of parts that make up the component exchanged at the aircraft.

[3] A third model for generating workloads and manpower requirements as a function of flying activity and logistics support structure was also developed during the study. However, due to a variety of difficulties in obtaining manhour data consistent with those used in the Navy manpower methodology, this model was not used extensively during the study.

policy options on measures of wartime aircraft availability, and (2) A queuing model for evaluating the effects of test equipment and manpower constraints on the component repair process.

Performance Evaluation

A version of Rand's Dyna-METRIC [Refs. 2, 4] model was the primary analytic tool used during the study. This model, an analytic representation of the aircraft support system, avoids four major limitations of current resource requirements methodologies (and most other models of the support system). Dyna-METRIC explicitly:

- Focuses on weapon-oriented performance measures (such as aircraft availability and sortie generation).
- Considers cannibalization[4] as a source of supply.
- Accounts for the transients in support system performance associated with variations in the level and intensity of operations.
- Deals with the interdependencies among resources and functions that characterize the support delivery process.

The model is based on the pipelines concept discussed in the Introduction and uses an extension of Palm's theorem to deal with the stochastic properties of the demand, repair, and resupply processes. In

[4]Mission-critical demands that cannot be satisfied from stock can be met by cannibalization, the use of parts from systems down for other reasons, or by expedited repair of components already in the maintenance pipeline. Traditional measures of supply performance show degradation even when these alternative sources are able to meet the material requirement. The contribution of cannibalization at both the WRA and SRA level to operational performance will be discussed further in Chap. IV.

addition, it embodies a capability to examine the effects of resupply or repair interruptions, alternative logistics support structures, claims by more than one aircraft type on a common resource pool, and demand distributions with a variance to mean ratio greater than one (compound Poisson processes).

Figure II-1 shows the various parts of the logistics structure modeled by Dyna-METRIC. Local repair and resupply of aircraft components (WRAs) for the flight line are modeled in detail. Scenario-driven missions and sortie demands, combined with historical rates of component removal at the flight line, provide the basis for component repair requirements in the shipboard AIMD. Removals by the flight line crews also create a demand against the shipboard supply system to provide a serviceable WRA for the aircraft. When the supply system cannot provide the requested spare part, the component is backordered, in effect creating a "hole" in an aircraft. These holes or shortages of WRAs can be consolidated at the aircraft through WRA cannibalization.

Dyna-METRIC was used to show the resulting aircraft availability with and without WRA cannibalization. Thus, the shipboard supply policy (which determines the quantity of spare parts) and the amount of WRA cannibalization (which moderates the effect of shortages on aircraft availability) are two important aspects of shipboard component repair and replacement measured by Dyna-METRIC.

WRA repair may require the repair of one or more SRAs (subcomponents), another aspect of the shipboard AIMDs modeled in Dyna-METRIC. The shop repairing the WRA removes an SRA and at the same time places a demand against the supply system for a spare serviceable SRA to

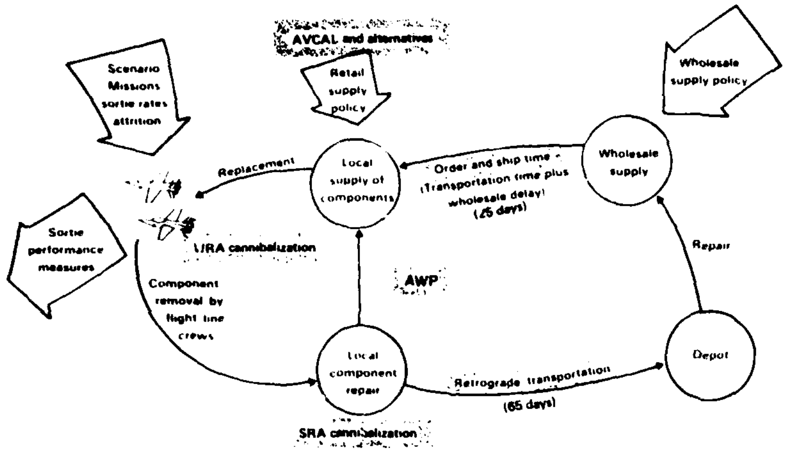

Fig. II-1—The representation of supply and related logistics resources in the Dyna-METRIC model

replace it. Inability to provide a spare SRA causes a backorder against that subcomponent and an AWP condition for the WRA. The WRA is then sent to an AWP locker until the appropriate SRA becomes available through SRA repair or resupply. When two or more WRAs are in AWP condition for different SRA backorders, the holes in WRAs can be consolidated by SRA cannibalization. Dyna-METRIC was used to evaluate SRA supply policy options as well as the effect of SRA cannibalization on AWP and its resulting effect on aircraft availability.

Certain types of repairs cannot be performed at the ship and must depend on retrograde transportation (currently about 65 days) to a depot repair facility. At the time a WRA or SRA is determined to be not reparable aboard ship, an order is placed with the wholesale supply system. When it can ship a component immediately, there is a transportation delay (currently about 25 days) in moving the component to the ship. When the wholesale system cannot provide the component, there is an additional order and ship (O&ST) delay while the component is backordered. Dyna-METRIC was used to predict the wartime O&ST delay given historical depot repair times and a wholesale supply policy for component spares.

Dyna-METRIC requires four classes of input data:

- A scenario that describes the support structure, the flying program by day, and unusual states of the support system, such as transportation cutoff.
- Component data describing the demand rate, maintenance turnaround time, beyond capability of maintenance fraction, resupply time, and characteristics of the demand distribution.
- Resources available to the system, including stock, manpower, and test equipment.
- A description of the relationships among components, and between components and repair resources.

The version of Dyna-METRIC developed for the Navy uses only the first three classes of input data. Due to the size of the study's data base, the fourth class was handled by a series of pre-processors which generate AWP projections for indentured components and for simulating the repair process. As will be discussed in Chapter IV, tests of the models using peacetime flying programs produced results that are quite consistent with the Navy's peacetime experience.

Maintenance Queuing

The second model used in the maintenance analysis was a mean value simulation of the repair process that evaluated maintenance queuing due to capacity constraints. After generating failures based on component demand rates and the scenario flying program, it scheduled repairs based on the stock position and test time requirements of each component.

The model employed a scheduling algorithm designed to minimize the number of "holes" in aircraft created by any one type of part, and demonstrated clearly the value of priority repair (known as expedited repair (EXREP) in the Navy) when maintenance capacity has the potential to severely constrain operational performance. Delays attributable to maintenance queuing were then input to Dyna-METRIC to evaluate the implications of maintenance delays. The results of the queuing analysis reported in Chapter V show how in the short run maintenance can compensate for shortages of stock, indentured components, test equipment, and/or manpower.

EXPLANATION OF PERFORMANCE MEASURES IN THE ANALYSIS

The study shows the results of policy and resource changes on aircraft availability. This availability is usually described by the terms PMC, FMC, NMC, NMCS, PMCS, NMCM, and PMCM. PMC is the average number of partially mission capable aircraft at a point in time, those capable of performing at least one of their assigned missions. FMC is the average number of aircraft fully mission capable and includes only those aircraft capable of performing all missions at a point in time. NMC is the opposite of PMC and therefore includes only those aircraft not capable of performing at least some of the required missions. The addition of the suffix S or M indicates that the cause of degraded capability is either supply or maintenance. Aircraft not available for supply reasons are those that are missing WRAs because of removals and unfulfilled supply requisitions. Those not available for maintenance reasons include aircraft being worked on at the flight line and aircraft undergoing maintenance or periodic inspections on the hanger deck but which do not have component holes.

The measures used in this study are modifications of PMC and FMC because the analysis deals only with a subset of components and reasons that aircraft are not available. In this document we will denote these measures PMCA, FMCA, and NMCA. PMCA is the average number of aircraft available for a given set of missions after aircraft with missing or nonfunctioning avionics are removed, <u>but before loss of capability due to engines, other components, and maintenance is considered</u>. NMCA represents the average number of aircraft non-mission capable because of avionics malfunctions and is therefore the number of aircraft nonavailable due to the subset of components considered in this analysis. Finally, FMCA represents that set of aircraft which have a completely functioning avionics suite.

III. MANPOWER

Manpower is an important determinant of maintenance capacity. This chapter describes the Navy's current manning methodology, identifies a potentially serious deficiency in that methodology, and outlines an alternative that would overcome the deficiency. A more detailed description of the manpower analysis is provided in App. A.

CURRENT NAVY MANPOWER MODEL--ACM-02

Approximately seven years ago, the Navy Manpower and Material Analysis Center, Atlantic (NAVMMACLANT) was tasked by the Office of the Chief of Naval Operations to develop staffing standards for aircraft intermediate maintenance manpower requirements. Prior to this effort, Aircraft Intermediate Maintenance Department (AIMD) manpower requirements were based on the subjective judgment of the individual claimant. The NAVMMACLANT model--designated ACM-02 [Ref. 8]--was to provide a systematic, reproducible methodology that could be applied objectively across the various AIMDs in the Navy.

The model has evolved to the point where ACM-02 is being accepted as the official Navy standard for developing I-level maintenance manpower requirements. ACM-02 has been extended over the total Navy environment and the resulting requirements are in the FY81 budget submissions. Compared with current authorizations, the ACM-02 requirements represent an increase of approximately 1700 billets, or about 10 percent, across the total Navy. The current authorizations and ACM-02 requirements for the Atlantic and Pacific Fleets are shown in

Table III-1. Basically, ACM-02 results in a shift in manpower billets with increases in the permanent party manpower at shore AIMDs and decreases in the squadron temporary additional duty (TAD) billets. The effect of ACM-02 for a typical carrier (CV) air wing is shown in Table III-2. Under ACM-02 requirements, a carrier AIMD would have approximately 80 fewer billets than are currently authorized.

ACM-02 Methodology

ACM-02 is basically an accounting model that uses previous aircraft maintenance experience, as recorded in the 3M data system, as the basis for determining the number of aircraft maintenance personnel required. It is an accounting model in that it multiplies per aircraft factors by number of aircraft to arrive at an aircraft component workload and divides workload by manpower availability to calculate billets; there is

Table III-1

ENLISTED PERSONNEL VALUES, FY81

	Current Authorization	ACM-02 Requirement
Atlantic Fleet		
NAS - Permanent	1933	2795
CV/LPH - Permanent	1487	1534
TAD (including OPDET)	2427	1875
Pacific Fleet		
NAS - Permanent	2056	3182
CV/LPH - Permanent	1201	1253
TAD (including OPDET)	2990	2153
Total	12094	12792

Table III-2

CARRIER AIMD MANPOWER

	Authorized	Required ACM-02
CVs (permanent) (13)	2320	2264
Average	178	174
Carrier air wing (TAD)		
A-6E/KA-6D	45	27
A-7E (2)	52	44
F-14A (2)	78	52
EA-6B	37	27
E-2C	23	20
S-3A	37	28
SH-3H	13	11
Total TAD	285	209

no predictive capability based on aircraft characteristics or operating environment or any statistical analysis (for aircraft workload) in the model. The model determines manpower at the work center level and calculates requirements by squadron. By accumulating the squadron manpower requirements, ACM-02 determines total manpower for a given AIMD.

Certain shops in an AIMD do not have aircraft maintenance workloads. These work centers--such as Material Control, Ground Support Equipment, Quality Assurance, Division Offices, etc.--are either position manned (i.e., a certain number of personnel are required) or manned on the basis of regression equations using independent variables such as number of aircraft, number of subordinate work centers, or support equipment maintenance workload. The resulting billets in these work centers are considered permanent shore station or ship requirements.

Personnel requirements for the aircraft component work centers in an AIMD are based on aircraft component maintenance (AM), support equipment maintenance (SE), and administrative support (AS) hours. For a given AIMD (ACM-02 is used separately for each AIMD), the steps below are followed to calculate manpower requirements in the production work centers:

1. The number of aircraft by type, model, series (TMS) that are supported by the AIMD is determined. For a CV, these aircraft will be the total number in the Carrier Air Wing assigned to the ship, ignoring differences caused by leaving aircraft at a convenient shore location. For an NAS, the aircraft supported will include the non-deployable squadrons (e.g., Replacement Air Groups), reserve aircraft, and some average number of fleet deployable aircraft that are usually at the base in peacetime.
2. Each type, model, series of aircraft has an average intermediate maintenance manhours per month (B value) determined from historical 3M data. The B value is fixed and does not depend on flying program or location. Multiplying the number of aircraft by the appropriate B value yields the total maintenance workload by aircraft type.
3. The total maintenance workload by aircraft type (AM hours) is spread to the production work centers using factors developed from 3M data. Each AIMD has a unique Z matrix that lists the precent of total workload that goes into each work center for

each type, model, series of aircraft supported by the AIMD (the columns of the Z matrix are aircraft type, the rows are work centers). All carriers are considered the same and have a common Z matrix.

4. For certain work centers, primarily avionics, the maintenance workload by TMS aircraft is further spread to Naval Enlisted Classification codes (NECs) using percentages based on 3M data. Each avionics work center has a table listing NEC percentages for sea, CONUS, and overseas locations for each type aircraft. These percentages usually do not total to 100 with the assumption that some part of the workload is not NEC specific. At this point in the process, each work center has workloads by NEC for each type of aircraft.
5. Support equipment maintenance hours are added to each work center. These SM hours represent a total value for a given work center for specific AIMDs (again, all CVs are treated the same) and are determined from 3M data. The ACM-02 document has a table for each work center that lists SM additives by AIMD.
6. Total aircraft component maintenance hours plus support equipment hours for a work center are divided by availability[1] to yield an intermediate billet figure. This value is used as the independent variable in a regression equation that determines Administrative Support (AS) workload for each work center. At this point, each work center has

[1] Availability is 60 hours per week at sea and 31.9 hours per week on shore.

aircraft workload by NEC for each type aircraft, a total figure for support equipment maintenance, and a total value for Administrative Support workload.

7. Billet requirements are then determined. For each squadron, TAD personnel are calculated on the basis of AM hours by NEC, dual coding NECs where possible; fleet squadrons of the same aircraft type get similar manpower requirements. Permanent party personnel are determined on AS and SM workload plus, at shore locations, permanent personnel are required to handle excess aircraft workload; that is, because of available hour differences between sea and shore, a shore AIMD may need extra personnel to handle the aircraft workload (for example, on ship 60 hours of work equals one TAD person, that 60 hours on shore equals the one TAD person plus one permanent person).
8. Paygrade matrices determine the grade structure for each work center.

The conversion of workload to manpower requirements requires human intervention and decision. Carriers are manned first to determine fleet squadron TAD requirements. Then, at NASs, these fleet TAD personnel are input into the model, and OPDET and finally permanent requirements are determined. The dual coding of NECs is somewhat subjective, with the philosophy that almost any skills in the same work center are compatible. ACM-02 does not require that a person has the needed combination of skills, but assumes that a person can be trained to fill the dual NEC requirement.

ACM-02 Updates

The ACM-02 model has been updated and modified over time in response to the suggestions and criticisms of the various manpower claimants and type commanders. NAVMMACLANT realizes some problem areas remain and the ACM-02 analysts constantly strive to update and improve the model. Two areas that are currently under investigation are the VAST work center and the development of B values for certain types of aircraft.

For aircraft that are VAST compatible, entries in the Z tables signify the percent of the total aircraft component workload that is attributable to the VAST work center. Currently, however, the ACM-02 model does not determine VAST manpower requirements based on this estimate of workload. The ACM-02 document contains tables for the VAST work center that specify manpower requirements based on the number of VAST stations and the number of maintenance shifts. These position manned values are used because the manpower claimants felt the ACM-02 manpower resulting from the workload calculations were not sufficient to cover the VAST work. The use of workload in determining manpower in the VAST shop is being analyzed by ACM-02, with the position manning tables being used in the interim. It should be mentioned that the number of people in the VAST work center is constrained by the facilities available. Given a specific number of VAST stations, there is a maximum number of people that can efficiently use the test equipment.

A second area under investigation is the calculation of separate B values for sea and shore deployments. Currently, ACM-02 uses a composite B value representing an average of the worldwide maintenance experience or each type of aircraft. Questions have been raised concerning differences between the maintenance workload for aircraft deployed on board carriers and those that are stationed at NASs. Since ACM-02 assumes independence of workload and flying activity, separate B values for sea and shore would be one way to attribute more work to the higher activity at sea (theoretically representing a wartime environment). This question of peacetime versus wartime workloads is discussed more fully in the next section.

From the point of view of the CABAL study, the biggest change in ACM-02 is the amount of workload currently in the avionics work centers compared with the workload found during the time frame of the DRMS. The earlier version of the ACM-02 document (dated January 31, 1978) used for the DRMS showed very small workloads for a large number of NECs in the avionics work centers. These small workloads led to the recommendation to move some repair actions off the CVs and centralize repair for those components at shore NASs. Such a consolidation of repair offered the benefit of a significant reduction in NEC manpower requirements, i.e., one or two repairmen at an NAS could handle the workload that currently requires one person on each of 13 carriers.

The current version of ACM-02 (dated March 30, 1979) shows a much higher amount of work in the avionics work centers. By increasing both the B value and the percentage of total work attributable to avionics shops, the current avionics workload is over 70 percent higher than the workloads used for the DRMS analysis. These two sets of workload figures are summarized in Table III-3.

Table III-3

MONTHLY AVIONICS WORKLOAD FROM ACM-02 MODEL

		DRMS			Current		
Aircraft	No.	B Value	Percent in Avionics Work Centers	Total*	B Value	Percent in Avionics Work Centers	Total*
EA-6B	4	414.4	.6859	1136.9	628.9	.8768	2205.4
A-6E	10	202.3	.6599	1335.0	277.8	.7970	2214.1
KA-6D	4	156.0	.5752	358.9	207.6	.7415	615.7
A-7E	24	154.3	.5088	1884.2	198.0	.7344	3489.9
E-2C	4	219.4	.7707	676.4	273.8	.9202	1007.8
F-14A	24	243.0	.4996	2913.7	295.3	.7269	5151.7
S-3A	10	223.2	.5749	1283.2	228.0	.8843	2016.2
SH-3H	6	105.5	.5810	367.8	125.7	.6722	507.0
Total Monthly Manhours				9956.1			17207.8

*Total = (Number of aircraft)(B Value)(Percent in Avionics Work Centers)

Probably a number of reasons have contributed to the growth of ACM-02 workload. The ACM-02 analysts have gotten "smarter" over time and are accounting for more of the workload now than previously. Prototype aircraft hours, or work that is miscoded and charged to a general model of aircraft (e.g., the F-14 versus the F-14A), is now spread to the various models of a given type of aircraft. SAF workloads and other component workload, such as assisting work centers, are also included in the B value. The AIMDs, realizing that historical 3M data are the basis for their manpower authorizations, are paying more attention to the proper collection and reporting of maintenance data. ACM-02 hours may also be increasing because of more component removals and/or longer repair times.

Regardless of the cause for the increase in ACM-02 workload, the higher personnel utilization reduces the potential manpower savings due to consolidation. The economies of scale disappear when skills are more fully utilized on board the carriers. The DRMS assumed that a workload of less than 10 hours per week would result in a billet's workload being transferred to a shore AIMD. The result of this assumption was a savings of 327 billets per fleet due to workload consolidation. Using the same assumption and the current ACM-02 workloads, the potential savings are reduced to 115 billets per fleet, or less than 20 per carrier.[2] If the ACM-02 workloads are escalated to wartime flying rates, the savings become only 83 per fleet. Furthermore, approximately 25 percent of the decreased billets could be gained by combining the two 12-airplane A-7 and F-14 squadrons into 24-aircraft units.

Although billet savings from transferring work from CVs to shore AIMDs may not be as extensive as the DRMS visualized, other benefits may still be possible. These potential gains from consolidation of workload include increased retention because of reduced sea duty, increased personnel productivity, increased test equipment utilization, and decreased repair times. The interaction between manpower, spares, and test equipment must be investigated to determine the effect on aircraft capability due to the consolidation of repair.

One major difference between ACM-02 and the CABAL manpower methodology is the statement of workload for determining I-level manpower requirements. The next section more closely examines the

---

[2] The calculation of billet savings resulting from transferring work from carriers to shore AIMDs is shown in Table A-5 of Appendix A.

ACM-02 workloads and raises the question of manning for the wartime mission based on peacetime experience without escalation for the more intense wartime flying program.

PEACETIME/WARTIME MANPOWER REQUIREMENTS

The objective of the CABAL manpower analysis is to measure the change in the quantity and type of personnel required to maintain fleet-deployable aircraft under various maintenance and personnel management alternatives. This objective entails the calculation of manpower requirements for the consolidated structure proposed by DRMS and comparison of the resulting requirements to those of the current maintenance concept. This comparison is made for the scenarios discussed in Chapter II.

The CABAL study assumes that resource requirements will vary with the flying activity of the aircraft supported. As the flying hours per aircraft increase, the number of component removals will increase and, therefore, there will be a larger demand for spare parts and I-level repair. This is a common and often used assumption of reliability theory. For example, the Navy's Aviation Supply Office computes the wartime stockage requirements for carriers by linearly applying the wartime flying factors to the removal rates experienced in peacetime. Carriers theoretically deploy with sufficient stock to meet wartime demands.

An aircraft squadron's Organizational-level manpower requirements are also determined on the basis of wartime flying activity. The preventive maintenance (PM) and corrective maintenance (CM) workloads contained in an aircraft's Squadron Manpower Document (SQMD) represent the wartime workload. Maintenance Requirements Cards are analyzed to develop PM factors per week, per flying day, per sortie, and per flying hour. The wartime flying program is applied to these PM factors to calculate total PM workload. CM hours are developed by using the wartime flying hours in a regression equation developed from peacetime data. The SQMD's organizational manpower requirements therefore represent wartime manning.

The ACM-02 model determines I-level manpower requirements without considering the flying program. The model factors are based on peacetime 3M data; the total maintenance workload for each aircraft type (B value) is found by dividing the total worldwide AIMD workload by the total number of aircraft supported. The ACM-02 output is therefore a peacetime manpower requirement.

The ACM-02 analysts originally attempted to find relationships between workload and flying activity. Because no significant statistical relationships could be discovered, it was assumed that the workload would not change as aircraft transition from a peacetime to a wartime environment. The absence of a significant relationship is not surprising when the peacetime data show little variability. If the annual flying programs in peacetime change very little from year to year, the data points will tend to cluster within a very narrow range of values. Statistical analysis will yield inconclusive results for such data.

In the original versions of the ACM-02 model, the question of the relationship of workload and flying activity was not of great importance. The ACM-02 workloads were very low, so a doubling or tripling of work would not affect the manpower requirements. However, as the ACM-02 factors have changed in recent years, AIMD workload has increased substantially, thereby increasing the utilization of personnel. Now an increase in work could, and in many cases would, increase the manpower required. It is therefore important that ACM-02, and the Navy, determine the effect of increased flying hours on the I-level maintenance workload.

What would actually happen to the I-level workload in wartime is difficult to determine and would require detailed analysis far beyond the scope of the CABAL study. As Figure III-1 shows, the assumptions of

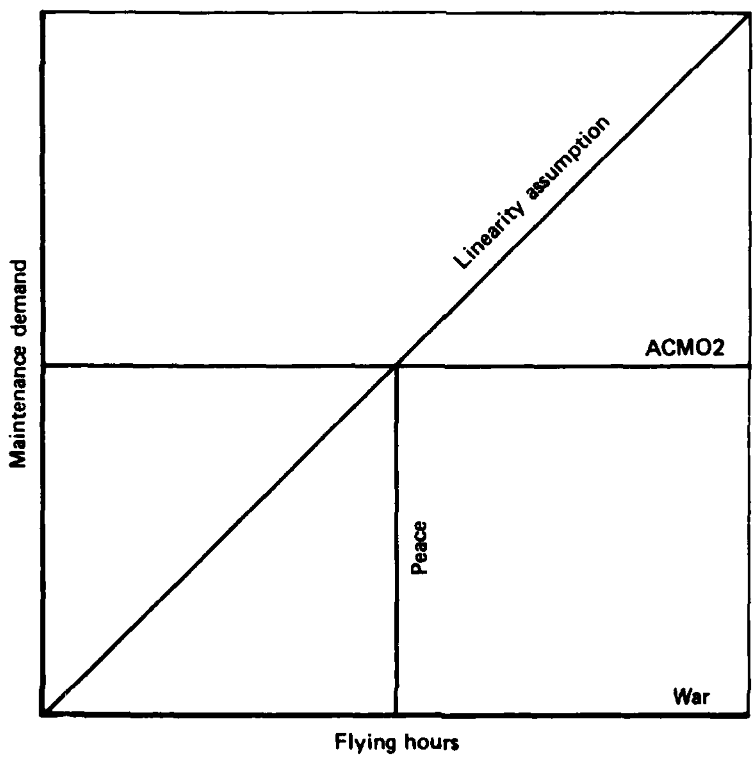

Fig. III-1 — Peacetime/wartime linearity assumption the ACM-02 model and the CABAL analysis probably define upper and lower boundary regions with the true workload occurring between the two values. The CABAL assumption is conservative in that it defines the upper limit on the wartime workload. Also, as mentioned above, the CABAL assumption of linearity is consistent with other methods of laying in resources for wartime.

If the ACM-02 manpower requirements are peacetime values, then a problem exists when determining the manpower effects of the consolidated structure. The manpower requirements under consolidation in peacetime could be compared with ACM-02 stated requirements. However, for the Indian Ocean and NATO scenarios, use of the ACM-02 billets as a measure of the current maintenance concept would bias comparisons in favor of the current structure. The CABAL analysis must determine what the I-level maintenance manpower requirements would be in wartime for the current maintenance structure to establish a proper baseline for comparison with alternatives. Also, the assumptions of the manpower portion of the CABAL study should be consistent with those used for the other resource measures. Since the spares and test equipment methodologies assume a linear relationship with the flying program, the CABAL manpower analysis also calculates workload based on flying hours.

Over and above the measurement problems in the CABAL study, there is the more important question of whether ACM-02 provides an adequate quantity and the proper mix of personnel to support wartime flying programs. If the workload does vary with flying activity, will carrier AIMDs experience shortfalls in manpower skills during wartime because ACM-02 supplied manpower based on lower peacetime workloads? A short exercise was performed to determine what the manpower requirements would be if a flying hour factor were applied to ACM-02 B values.

The deckload of the CONSTELLATION was chosen as a base case and the TAD manpower requirements required by ACM-02 were placed in the AIMD. The ACM-02 model was used to determine the workload. Flying hour factors were found by dividing the average flying hours per aircraft per month in wartime by the peacetime flying hours. The wartime flying programs used to determine these factors were from the specific aircraft's ROC and POE flying hour objectives. The peacetime flying programs were those experienced during the time frame of ACM-02's B values. These factors vary from 1.4 to 3.6--that is, the wartime flying program was from 40 percent to 360 percent more intense than the peacetime program. These factors were then applied to the ACM-02 billet workloads. The resulting workload (termed wartime work) was then divided by an availability of 60 hours per week to calculate new billet requirements.[4]

A number of the TAD billets (17) defined by ACM-02 had no corresponding workload. These billets represent work not covered by ACM-02 (the EA-6B ECM pods) or relatively new skills for which historical experience was not yet available from the 3M system. These "new" NECs are added to the ACM-02 TAD list by the SQMD analysts through contact with the appropriate squadrons. When no workload was available for a billet, it was assumed that wartime requirements were equal to

[3] The factors contained in the most recent ACM-02 publication were used to determine workload by NEC.

[4] The detailed results of this exercise are given in Table A-3 of Appendix A.

peacetime requirements. This assumption downplays the potential shortages.

The wartime analysis also places a limit of 24 TAD billets in the VAST work center. The VAST work center is currently manned by ACM-02 on the basis of manning tables rather than by the actual component workload. For a four-station, two-shift operation on board a CV, ACM-02 places 30 billets in the VAST work center. Of these 30, 9 are permanent ship billets and 21 are TAD from the aircraft squadrons. The use of the manning tables represents constraints due to the facility limitations in the VAST area; only so many people can work at the stations at a given time. As mentioned, the wartime analysis raises the maximum number of TAD billets to 24.

The wartime workload appears to require 31 component, or TAD, billets in the VAST shop. This workload is above the maximum equipment capability of the work center. Either more stations must be added, failed components must be shipped off the CV for repair, or other test equipment will have to pick up some of the VAST workload. The facility constraint was placed on the specific aircraft by removing 4 billets from the F-14 squadrons and 3 billets from the S-3 squadron. Although the F-14 squadrons had workload requiring 12 billets and the S-3 workload for 13 billets, only 8 and 10 respectively were placed in these squadrons.

The results of the wartime analysis are shown in Table III-4. For each aircraft, the number of personnel defined by ACM-02 is given followed by the wartime requirement, if the wartime number is different. A single entry for a work center implies that the wartime factor did not change the manpower requirement. Across the carrier air wing, the wartime manpower is 39 billets, or 25 percent, above the current ACM-02 definition of manpower requirements.

The manpower shortfall is most acute in work centers where the peacetime utilization is high, such as the Electrical/Instrument shop. Much of the work in this area is not specific to NECs. When the flying hour factor is applied to the peacetime workloads, almost twice as many personnel are required as are specified by ACM-02. Large shortfalls also exist in the SACE/INS work center.

Work centers where there are relatively small NEC workloads, such as COMM/NAV and ASW, are affected only slightly or not at all by increasing the workload. The wide range of NECs and the relatively

Table III-4

PEACETIME/WARTIME MANPOWER RESULTS

Shop	F-14 (24)	A-7E (24)	A-6/ KA-6 (10/4)	E-2C (4)	EA-6B (4)	S-3A (10)	SH-3H (6)	Total (86)
COMM/NAV	6	10	5/6	5	4	2	3	35/36
ELEC/INST	2	2/4	2/4	1	1	1/2	1/2	10/16
Fire ctl	12/14	6/8	-	-	-	-	-	18/22
Radar/ECM	4	6	2	2/3	12/15	2/4	-	28/34
SACE/INS	2/4	4/8	7/9	4	3	1/5	-	21/33
VAST	6/8	2	-	4	-	9/10	-	21/24*
ASW	-	-	-	-	-	2/3	3	5/6
Mod rep	2/6	-	4	-	2	2/4	-	10/16
Total billets	34/44	30/38	20/25	16/17	22/25	19/30	7/8	148/187

*Facilities constraint.

small non-NEC specific workloads allow these shops to easily absorb additional work.

Certain aircraft types are affected more severely than others when workload is increased. The F-14, S-3, and A-7 comprise 29 of the total 39 billet difference between peace and war. This is important because these aircraft represent the fighter, attack, and antisubmarine capabilities of the carrier. The S-3A, because of the significant increase in flying hours in wartime, requires over 50 percent more personnel.

The average utilization of personnel in the various work centers increases from a range of 15 to 60 percent in the peacetime case to a range of 30 to 90 percent with the wartime workloads. This increase in utilization further reduces any manpower savings that might accrue from the DRMS recommendation to consolidate repair actions.

The above exercise highlights a potential problem in the capability of AIMD manpower to respond to wartime demands. The linearity assumption applied in the exercise may overstate the effect of flying hours on workload. However, where peacetime utilization is high, such as in the Electrical/Instrument and SACE/INS work centers, any increase in workload from additional flying hours will overburden the manpower resources and cause problems in meeting the combat requirements of the carrier's aircraft.

Implicit in the analysis is the assumption that there are no other elements of the logistics system that are constraining the component workload. That is, there are sufficient test equipments and repair parts to preclude bottlenecks in the intermediate repair operations.

The VAST shop does not have enough stations to support all of the wartime workload. This implies that failed components will begin to form backlogs in the VAST area. Since VAST may feed workload to other work centers, the total wartime workload calculated above may not be accurate.

Although the current VAST capability appears to violate the assumption of no constraints on workload, manpower requirements should still be determined on the total anticipated (unconstrained) workload. To make other assumptions may lead to manpower shortfalls. Undoubtedly, priority repair procedures would be adopted in bottleneck areas. Such a priority system would depend on the importance of components that cause "holes" in aircraft. It would be difficult, if not impossible, to anticipate what workload would be generated. To ensure an adequate supply of personnel, the manpower analysis must assume that all projected workload will exist during wartime.

The calculation of manpower, whether by a simple exercise as outlined above or by a sophisticated simulation model, requires an accurate estimate of anticipated workload. In the period of one year, the avionic workload of the ACM-02 model increased over 70 percent. The next model iteration may result in further increases in work. Problems arise in the extraction and use of proper factors from a data system as diverse and complex as 3M. A significant effort was made during the CABAL study to locate accurate measures of failure and repair data and still the accuracy of the resulting workload calculations is uncertain.

An alternative to the current philosophy of determining manpower requirements on a squadron TAD basis may alleviate the apparent shortfall in personnel. This alternative, termed AIMD manning, is discussed in the next section.

AIMD MANNING

The wartime requirement of 187 I-level avionic component repair billets per carrier is based on the current method of supplying personnel to the carrier AIMDs. AIMDs have two types of personnel--those who are permanently assigned to the air station or ship and those who are sent to the AIMD from the operational squadrons the AIMD supports. For fleet deployable squadrons, these latter personnel are termed Temporary Additional Duty (TAD); for non-fleet deployable squadrons stationed at NAS's, these personnel form the Operational Detachment (OPDET). Both TAD and OPDET personnel[5] are theoretically responsible for the I-level component workload generated by their squadron's aircraft. While the ship or station AIMD has an authorization statement for their permanent cadre, the TAD personnel are identified in the aircrafts' Squadron Manning Document.

The concept of placing I-level personnel in the operational squadrons was developed for two reasons. First, it allowed the component repair portion of I-level manpower to move with the aircraft so that the repair capability was at the location of component failure without duplicating personnel at both an NAS and a CV. The second reason was that a self-contained squadron could deploy to any location and bring the necessary maintenance personnel with the aircraft.

---

[5] This section will concentrate on fleet deployable TAD personnel although similar arguments hold for the OPDET billets.

ACM-02 determines a squadron's TAD requirements by looking at the component workload of the squadron's aircraft. Assuming deployment on board a CV, ACM-02 calculates workload for each NEC by manipulating the aircraft's specific B value, Z matrix, and NEC percentages. TAD billet requirements are then determined by dividing NEC workload by availability and dual-coding billets with primary and secondary NECs wherever possible. Squadrons of like aircraft have the same quantity and type of TAD billets.

When an aircraft squadron transitions between sea and shore, the squadron assigns TAD personnel to the appropriate AIMD. The AIMD acts much like a production facility, supporting all aircraft that are assigned to the base or ship. The AIMD commanding officer makes no attempt to segregate component failures by specific aircraft squadron, but assigns failed components to properly trained individuals regardless of the source of the failure or the source of the TAD repairman. A paradox therefore exists between how I-level manpower requirements are determined and how the resulting manpower is actually utilized. Although TAD personnel requirements are determined by considering the squadron in isolation, the TAD personnel work in a consolidated environment.

MANPOWER REQUIREMENTS

One result of the current squadron TAD concept is an apparent overstatement of manpower requirements caused by the "integer" penalties of supplying whole billets for pieces of the overall workload. For example, in a typical carrier air wing each squadron has workload in the

COMM/NAV shop for the AT6609 NEC, and therefore each squadron has a billet[6] identified with this NEC. This results in nine people with an AT6609 NEC and a total workload across all aircraft of less than 70 hours per week. Obviously, manpower billets could be reduced if there were commonality in certain skill areas across aircraft types at a given location.

This overstatement of requirements, coupled with manpower shortfalls, is recognized and controlled for when squadron TAD personnel are assigned to AIMDs. As a carrier prepares for deployment, the AIMD officer dètermines the number and types of personnel he will need. This predeployment calculation is based on his knowledge of the aircraft to be supported and their historical workloads. The AIMD officer, in conjunction with the Carrier Air Group (CAG) Maintenance Officer, then determines which operational squadrons can supply the needed personnel. He may ask one squadron for a radio repairman and another for a TACAN person. Therefore, instead of receiving all the TAD personnel associated with the squadrons, the CV AIMD officer will request only those personnel he feels are necessary to provide sufficient repair capability. Any TAD personnel not sent to the AIMD remain with the squadron to assist on the flight deck as troubleshooters or to work in the organizational level work centers.

The personnel savings possible with an AIMD manning approach can be approximated by examining the workloads generated from ACM-02. Using the wartime workloads developed in the last section and summing across all aircraft, the total work for each NEC can be determined. Dividing

[6] Some of these billets are dual-coded with other NECs.

the total NEC workload by availability (60 hours per week) yields the number of AIMD billets by NEC.[7] These values are shown, along with the current ACM-02 and the wartime TAD figures, in Table III-5.

The wartime squadron TAD requirement of 187 billets is reduced to 147 billets when manpower is determined on an AIMD basis.[8] Although the total AIMD wartime requirement of 147 is almost the ACM-02 figure of

Table III-5

SQUADRON TAD AND AIMD MANPOWER REQUIREMENTS

	ACM-02	TAD Wartime	AIMD Wartime
COMM/NAV	35	36	18
ELEC/INST	10	16	14
Fire control	18	22	17
Radar/ECM	28	34	28
SACE/INS	21	33	27
VAST*	21	24*	24*
ASW	5	6	4
Mod rep	10	16	15
Total	148	187	147
Utilization rate	15-60%	30-90%	90+%

*VAST shop manpower is constrained to facility capacity.

---

[7] Table A-4 in Appendix A describes the derivation of the AIMD wartime requirements.

[8] Approximately 15 of the 40 fewer billets are due to combining the two squadrons of F-14s and A-7s into 24 aircraft squadrons. The combining of squadrons of like aircraft has been analyzed by the Center for Naval Analyses as part of their effort in the CABAL study. The estimated 15 billet savings is based on comparing the wartime TAD requirements of the F-14 and A-7 squadrons with the requirements indicated by dividing total aircraft workload by availability. The resulting number may differ slightly from CNA consolidated squadron results.

148, the mix of people is still important. Excess requirements of 19 billets in certain shops offset shortfalls of 18 billets in the remaining avionics work centers. For example, in the COMM/NAV shop, low NEC workloads cause the AIMD manning requirement to be only half the total squadron TAD values. On the other hand, the high peacetime utilization and a large amount of non-NEC specific workloads in the Electrical Shop force the wartime AIMD requirement to be greater than the current ACM-02 level of manning (although less than a wartime, squadron TAD requirement). Overall, there are shortfalls in Electrical/Instruments (AEs), SACE/INS (for three NECs--AE7116, AE7149, AQ7953), VAST, and Module Repair, whereas excess capacity is present primarily in COMM/NAV.

Personnel are almost fully utilized under the AIMD wartime option, thus negating any savings due to consolidation of repair. Furthermore, the difference in personnel availability between sea and shore environments may actually force the manpower requirement to be larger if workload is transferred to shore AIMDs.

In addition to reducing the overall requirement statement, manning on a consolidated basis may reduce training workload. The NEC dual coding specified by ACM-02 for a number of TAD billets places a training burden on the AIMDs. With consolidated manning, the need for dual coding disappears. Although cross-training would be beneficial, it is not required with AIMD manning.

MANPOWER MANAGEMENT

Determining I-level component repair billets on the basis of the total AIMD workload may force a change in the management philosophy of I-level personnel. The economies of consolidated manning imply that there are insufficient billets to provide every squadron with the full complement of skills necessary to cover their aircraft workloads. The shortfall is the 40 billet difference between the 187 TAD wartime and the 147 AIMD wartime requirements listed in Table III-5. Associating billets with operational squadrons may still be possible, but the billets would have to be distributed on a selected basis.

The assignment of some TAD billets to squadrons would mean that only certain types of aircraft would have selected NECs identified in their SQMDs. For example, there were only three AT6609 billets required under the consolidated approach; therefore, only three of the nine operational squadrons would have that skill identified in their manning documents. This practice of selected manning is currently used by ACM-02 in the Module Repair work center. Although every squadron has some module repair workload, only five of the squadrons (EA-6B, A-6E, S-3A, and the two F-14) have module repair TAD billets.

The home NAS bases of the aircraft could be considered when determining which squadrons are provided the specific NEC billets. Since multiple aircraft types often share a given NAS (e.g., F-14/A-6 at Oceana and F-14/E-2 at Miramar), one assignment rule might be to supply skills to only one of the aircraft types assigned to an NAS. Problems would arise, however, in the different basing schemes of the Atlantic and Pacific fleets. A number of other problems arise from having the operational squadrons control I-level personnel. The CV AIMDs currently have no requirement statement for component repair personnel but rely on the squadrons they support to provide properly trained technicians. The squadron maintenance officers must therefore continually monitor their I-level TAD personnel and plan the proper training programs to ensure they can provide the needed people. This is a significant management effort for the squadrons and, if not properly performed, can affect the capability of the CV AIMDs.

Even with adequate planning, problems do arise. As new personnel are assigned to squadrons, the maintenance officer interacts with the Fleet Replacement Squadrons to schedule the technical training necessary to attain specific NECs. After completion of the formal course work, the NAS AIMD is tasked to provide practical, or hands-on, training. The increasing length of the training courses for highly technical avionics components creates very close scheduling. With delays in the assignment process, personnel often go on deployment prior to completing the full training cycle. The CV AIMD must therefore provide a substantial amount of on-the-job training.

Unanticipated attrition can create even larger problems. If a person cannot successfully complete a training course or cannot deploy for personal or medical reasons, a shortfall occurs in CV AIMD personnel. Such shortfalls may be overcome by cross-training available personnel, or the squadron may have to fill the billet by pulling someone from an organizational maintenance work center. The AIMD will often prefer an unskilled maintenance man to none at all. A third option is to transfer a person from another Carrier Air Group or from an

NAS AIMD. This "cross decking" of people is discouraged and treated as a last resort because of its negative effect on retention.

Although the squadron's manpower documents have a list of required TAD personnel by skill, the actual set of TAD people is often a function of the resources of the Carrier Air Group and the associated CV AIMD. Personnel available from other squadrons and from the AIMD permanent party affect the set of billets each squadron assigns as TAD. Reassignment to a new carrier may create mismatches between the set of manpower the squadron has planned and trained for and what is required by the new CV AIMD.

Finally, the AIMD is somewhat at the mercy of the squadrons to provide the "best" people. To offer their personnel a wide range of experience and to increase their technical personnel base, squadrons will often send O-level maintenance men through I-level training courses. Because TAD billets are not identified by name, squadrons have a choice in whom they send to the AIMD. There may be a tendency to keep a more qualified individual for the flight line or organizational level shops, especially if the squadron maintenance officer has weaknesses in those areas and feels the AIMD can cover for the less qualified individual.

TOTAL AIMD MANAGEMENT

A second, potentially more attractive, I-level management philosophy would remove the TAD personnel from the operational squadrons and assign all I-level billets to the AIMDs. Component repair personnel would still move from CV to NAS as the aircraft transitioned, but personnel would be TAD from AIMD to AIMD rather than from squadron to AIMD. Such a strategy would remove the management burden from the operational squadrons and give the AIMDs better visibility and control over their total work force.

The actual implementation of total AIMD management could take a number of different forms. The first step would be to determine the number and type of I-level component repair billets necessary to support the aircraft assigned to each CV. The AIMD wartime option outlined in Table III-5 represents the number of such billets for the CONSTELLATION (or any CV with a similar deckload). The personnel complement would then be segregated into teams that would accompany the aircraft to their home NASs.[9] The formation of such teams would not be difficult because many NECs are aircraft specific. Common skills across aircraft exist primarily in the COMM/NAV and Electrical/Instruments work centers.

Because AIMD manning results in a lower requirement statement than squadron TAD manning, some shortfalls will exist when assigning skilled billets to support NAS workloads. The uncovered workloads are relatively small -on the order of a few hours a week--and occur primarily in the COMM/NAV shop. This work center has the lowest personnel utilization with squadron TAD manning and therefore realizes the biggest gains from consolidated manning. Because of low utilization in this shop, sufficient excess capacity may exist among the [illegible] and permanent party at NAS AIMDs. Some small number of additional billets may be required at some NASs, but the size of the teams under AIMD

[9] Possible team compositions for a typical carrier in the Atlantic and Pacific are outlined in Tables A-6 and A-7 of Appendix A.

management is approximately equal to the number of TAD billets ACM-02 would supply to the various shore AIMDs.

Once team compositions are determined, the next step is to determine how personnel would be assigned to CV/NAS teams and whether carriers or air stations would manage the I-level billets. One option would be to form pools of personnel at each NAS that would be drawn upon to supply manpower to deploying carriers. This option has the problem of ensuring equitable sea/shore rotation for all personnel in the pool. Also, there may be a tendency on the part of the NAS AIMDs to keep the more qualified personnel to support station operations and send the less qualified people to the CV AIMDs.

A preferable option would be to identify personnel with specific CVs and to allow the CV AIMD officer to manage the resulting billets. A repairman would be associated with a specific CV for his three year tour. There would be no question of whom would deploy with a CV or when a person could expect to be at sea. When a carrier left for deployment, the persons associated with that carrier would transition from NAS to CV AIMD. Allowing the CV officer to manage all the billets in his AIMD would provide him greater control and visibility over his assets and allow a more direct interface between the AIMD manager and the requirements, training, and assignment processes.

Each CV/NAS team could have a leader to act as an interface between the team and the NAS AIMD. The leader, an E-5 or E-6, would coordinate the activities of the team in its support of the NAS AIMD and would monitor both technical and hands-on training to ensure the capabilities of his team were maintained at an adequate level. The indirect support personnel (mess, laundry, etc.) for the CV team while stationed at the NAS would be provided by the CV. These support people would be those provided in the authorization statement to augment the CV during deployment.[10]

As transfers and attrition created holes in the CV AIMD personnel complement, the AIMD commanding officer would request replacements from the personnel distribution system. Interaction (most likely by the team leader) with the appropriate Fleet Replacement Squadron and NAS AIMD would channel the replacement personnel through the proper training cycle.

BENEFITS AND LIMITATIONS

Prior to changing from a squadron to an AIMD management philosophy, all the advantages and disadvantages must be considered. The one quantitative benefit is the reduced personnel requirement. However, manpower based on consolidated AIMD workload could still be associated with the operational squadrons on a selected basis. Other potential benefits and limitations are qualitative and subjective.

Removing their TAD billets would certainly reduce the personnel management load of the squadrons' commanding officers. They could then devote more of their time and effort to their operational mission--flying the aircraft. Squadron officers may feel that control of the TAD personnel somehow affects the support they receive from the AIMD. However, AIMD officers assign components to repair personnel on the

---

[10] Support personnel for TAD billets are identified in SQMDs. These personnel would be transferred, along with the TAD billets, to the CV authorization list. The support would be a part of each CV/NAS team.

basis of the overall needs of the total aircraft they support. In reality, squadrons may sometimes interfere with the operations of the AIMD through interactions with their TAD personnel.

The CV AIMDs should greatly benefit from the removal of the squadron filter in the requirements, personnel assignment, and training processes. The CV AIMD would communicate directly with the various parts of the personnel system rather than relying on the squadrons. With the assignment of personnel to their AIMD for full tours, the CV AIMD officer would have better visibility over the strengths, weaknesses, and anticipated shortfalls in his personnel assets. The continuity of his work force should improve overall productivity and reduce his training workload.

The CV AIMD would no longer have the squadron O-level pool as a fallback for unanticipated attrition. This would benefit the squadrons, but could create problems in filling sudden holes in the personnel complement. As newly assigned skilled personnel were directed to NASs for assignment to CV AIMDs, a priority mechanism could direct them to the CV with the greatest need. With sufficient pipeline supply, unanticipated attrition could be handled more efficiently with AIMD management than with squadron management.

The NAS AIMDs should feel little effect from the change in management philosophy. They would still receive a complement of repair personnel to support the aircraft coming from CVs, but the personnel would be TAD from the CV AIMD rather than from the squadrons. No additional management duties should arise, and the on-the-job training workload would be reduced because of the elimination of dual-coding billets.

The personnel distribution system should also benefit from AIMD management. Rather than having many operational squadrons requesting and competing for new personnel, a limited number of CVs would require I-level component repair billets. New lines of communication between the CV, NAS, and assignment communities would have to be established, but the overall interface should be improved.

One perceived problem is the loss of squadron capability to deploy anywhere with all the necessary support personnel. With the ever increasing reliance on automatic test equipment, deployments may not be easily accomplished. Furthermore, since many skills are unique to aircraft types, it would not be difficult to identify the appropriate I-level personnel from the aircraft squadron's CV team.

All of the above issues, and any additional benefits and limitations, must be considered before changing to a new management philosophy. However, the reduced manpower requirements and training workload and the increased control of the personnel by the AIMDs offers a considerable initial advantage.

IV. TEST EQUIPMENT

Test equipment is a key determinant of maintenance capacity. This chapter describes the CABAL test equipment analysis. It first outlines the role of test equipment in the maintenance process and presents data on test equipment utilization. It then presents the results of the analysis of alternatives for reducing the VAST capacity shortfall identified during the study.

TEST EQUIPMENT AND LOGISTICS PERFORMANCE

Test equipment capacity affects maintenance performance and aircraft availability through its influence on repair turnaround times. Actual test time accounts for a very small fraction of turnaround time. In fact, administrative delays[1] account for over half of the average time from removal of a component until it is restored to a serviceable condition. Only about 10 percent of the 3 to 3.5 day repair portion of turnaround time is spent on the test stand. The remaining three days are consumed by in-shop administrative delays or maintenance queuing.

In-shop delays occur in peacetime because of peacetime resource utilization policies rather than facility capacity constraints. Full manpower capacity of 60 hours per week is not required and is not

[1] These delays include the processing time from removal of the component until it is picked up by job control, scheduling time for job control to direct the component to the appropriate shop, and AWP time during which repair action must be suspended because of stock shortages. Average actual turnaround time for the avionics components considered in the CABAL analysis was slightly more than 10 days. Of this, about three days were spent in the processing and scheduling pipeline segments, and an average of four days was spent AWP.

scheduled during peacetime. Although this does permit some maintenance queues to develop in peacetime, they can be worked off quickly if the carrier is called upon to support a wartime flying program.

TEST EQUIPMENT UTILIZATION

Figure IV-1 shows that facility capacity should not pose a wartime constraint on repair of most components. The figure shows projected wartime utilization of the 50 most heavily loaded pieces of test equipment considered in the CABAL maintenance analysis.[2] Only one test stand--VAST--has a daily wartime capacity requirement of more than 24 hours/day; only seven have a daily requirement of more than 12 hours/day.

This measure of test equipment capacity demand does not, of course, consider test stand availability, an important determinant of capacity supply. One rationale for the DRMS [Ref. 9] recommendation to consolidate repair capacity ashore was the assumption that test equipment on carriers would have poor wartime availability. This was assumed because most equipments are one-of-a-kind and not all of the parts needed to repair them could be stocked on the carrier.

The preferred approach to the analysis of test equipment availability would be to use availability data to project test equipment supply. Unfortunately, no data source for availability estimates could be identified.

---

[2] The CABAL analysis concentrated on test equipment with a unit cost greater than $5000 because high cost equipments were the most likely to involve significant costs to relieve capacity constraints, or significant savings if the analysis supported consolidation of repair for some classes of items. There were 130 pieces of test equipment that met this cost constraint.

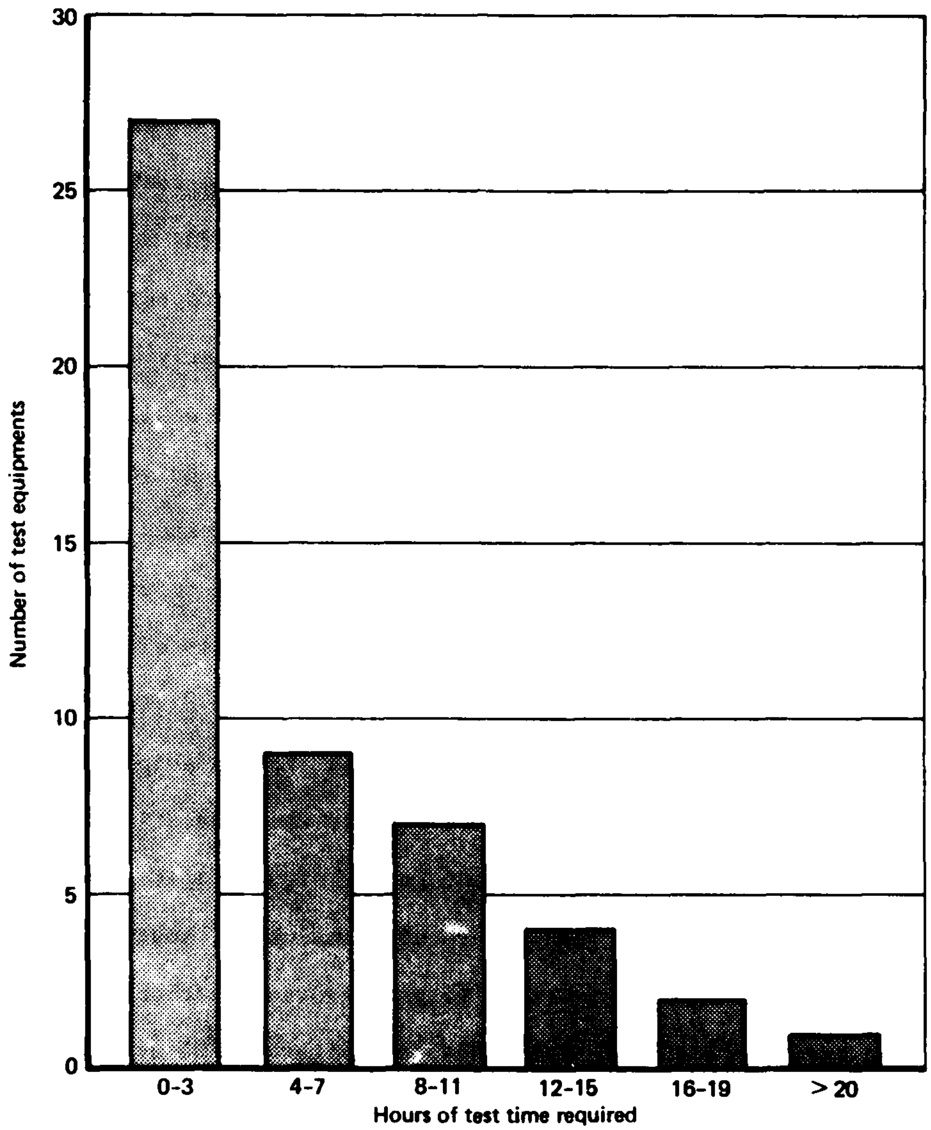

Fig. IV-1 — Distribution of daily test time demand:
Fifty high cost, "high" utilization test equipments

An alternative approach to testing the more limited hypothesis that shipboard test stand availability suffers from low equipment population and a wide range of potential part requirements is to compare afloat and ashore repair times for components repaired on the same test stand. Peacetime repair times at shore-based and shipboard AIMDs were compared on the assumption that if, under the current repair structure, test equipment availability on board the ship was significantly worse than that at shore-based facilities, the afloat repair time would be longer. The comparison showed that only two test stands had unequivocally worse repair times afloat. Since the demand for these two stands is low, it is likely that only one installation would be provided to either a shipboard or a shore-based AIMD. Hence, the repair time differences even for these two stands are probably attributable to differences in repair priorities afloat and ashore rather than to low shipboard test equipment availability. These results suggest that peacetime test equipment availability for the current repair structure is no worse aboard the carrier. These results are not conclusive, however, because deployed carriers in peacetime tend to get favored treatment for spare parts and special technical assistance that might not be available in wartime.

The combination of this information on repair times and that concerning test equipment utilization implies that the lack of test stand availability data did not severely limit the analysis. The repair time comparison may simply have shown that availability is low both afloat and ashore; the utilization data indicate that, except for a few equipments, availability is probably not very important.

Two qualifications to the above observation on the utilization data in Fig. IV-1 are:

- o Low utilization does not, by itself, constitute a case for removing test equipment from the carrier.
- o Demands for VAST capacity exceed available supply, and the shortfall could severely degrade aircraft material condition.

Alternatives for relieving the VAST capacity shortfall are discussed in the next section. Before turning to that analysis, however, it is important to stress the limitations of the utilization analysis as a basis for decisions on test equipment allocation.

The low projected demand for test station capacity suggests that even if availability were as low as 50 percent for most equipments, test equipment availability should not limit operational performance. The data might also support arguments for consolidating test capability to improve utilization of expensive test equipments.

The combination of low availability and low utilization, however, does not mean that these stands would not affect performance. Equipment outages during periods of peak demand clearly could affect aircraft material condition if supply stocks were not adequate to cover an increased maintenance turnaround time.

Nor does low utilization alone indicate that the equipment should not be installed on carriers. The test equipment required to support current weapons systems has already been procured, and thus represents a "sunk cost" that favors the current maintenance structure compared with alternatives. From an economic standpoint, even if this equipment cost more than the stock that would be needed to replace it on the carrier, the fact that it has already been bought means that there is currently no tradeoff between equipment and stock investments. Finally, even where test equipment is expensive and has low demand, it may be more economical to outfit each carrier with the required test stands than to fund the extended repair pipeline that would result if repair were not authorized on the carrier.

Both of these arguments illustrate the importance of considering the implications of maintenance policy for the logistics system as a whole rather than individual functions or resources. In fact, one of the tasks of the Navy's Level of Repair (LOR) analysis is to consider explicitly these tradeoffs among elements of the logistics system as a basis for policy decisions concerning the allocation of repair capability and capacity. One weakness of this LOR process, however, is that it normally does not exercise its option for considering shore-based AIMD repair as an alternative to either carrier or depot repair. This alternative should be explored in LOR analysis for new weapon systems--where potential tradeoffs among resources can be exploited.

THE VAST CAPACITY SHORTFALL

As was noted above, the projected wartime demand for VAST capacity exceeds the available capacity. Total daily test time demands are projected at 134 hours[3] versus the 84 hours available if wartime test

[3] This projection of test time demand is based on: (1) removal rates and test times experienced in peacetime and (2) the wartime flying program used to develop spares requirements.

stand availability equals that in peacetime.[4] The VAST utilization fraction is thus projected at 1.6, suggesting that nearly 40 percent of the workload generated each day would enter an infinite maintenance queue.

The actual rate of backlog generation would depend on the carrier's flying program and wartime removal rates. The key point is that activity levels anywhere near those programmed, unless they are interspersed with long periods of no flying activity, will generate increasing backlog levels that are virtually certain to have an adverse effect on performance.

The composition of the VAST backlog in terms of the items awaiting service is dependent on the scheduling rule used to induct components for testing. The effect on performance of the current VAST capacity shortfall, and the results of a scheduling algorithm designed to minimize the effect of the shortfall, are discussed in Chapter V. The goal is to identify alternatives for relieving this constraint by reducing VAST test time demands or increasing the supply of available test time. Thus the first problem is to characterize projected demands for VAST capacity.

There are two obvious alternatives for reducing test time demand: (1) total testing demands could be lowered by reducing the rate of repair generation or (2) some components currently repaired on VAST could be assigned to other on-board test equipment or moved off-ship for VAST repair.

---

[4] Although no formal data on VAST availability were located during the study, informal estimates placed average peacetime availability at about 3.5 out of 4 installed stands. This equates to about 84 hours of VAST capacity per day.

The number of removals requiring test could be reduced by either improving component reliability or reducing the flying program. Identification of cases in which reliability improvement investments are warranted or feasible was beyond the scope of this study.[5] The assumed linear relationship between removals and flying hours does, however, suggest that reducing the flying program would limit the VAST capacity shortfall.

Although the capacity shortfall could ultimately force reduced flying, using test equipment capacity as the basis for programming flights would clearly be putting the cart before the horse. However, knowledgeable Navy officials have questioned the ability of the S-3A aircraft to ever achieve the utilization rates that were assumed in the workload projections considered here. If the S-3A flying program were held to the level currently programmed, about two-thirds of that in the estimates of wartime VAST capacity above, VAST utilization would fall from 1.6 to 1.32. Thus it would ease, but not fully resolve, the capacity shortfall.

The next demand-reducing alternative would be to move some components off the shipboard VAST. There are a number of possible ways to identify these components. The components to be reassigned could be

[5] The total demand for test could also be reduced by modifying test routines to reduce the test time per removal. This option, like that of improving reliability, represents an engineering problem whose resolution is beyond the scope of this study. The histograms of test time requirements and the value of test time presented later in this chapter should, however, be useful in identifying components upon which reliability and test time improvement efforts could be profitably concentrated.

SRAs, WRAs, or some combination of both. Or, the components could be moved to other shipboard test equipments or ashore. Finally, selection could focus on items with high daily test requirements (which would limit the range of items affected by the change) or low demands (which would affect a wide range of components), or rely on some form of marginal analysis to establish which should be moved based on an economic criterion.

WRA shortages have an immediate impact on aircraft availability. SRA shortages have a less direct effect--they degrade availability only when they cause WRA shortages due to AWP. Since the effect of SRAs is indirect, the first approach to reducing the capacity shortfall might be to allocate the available capacity to WRA testing only. Moving SRAs off VAST, however, would have little effect on backlog generation. Much of the SRA test time that was once assigned to VAST has been moved to SRA testers such as the Hybrid Automated Test Set (HATS) and the Computer-Aided Test Set (CATS). Since WRA test requirements account for over 85 percent of project VAST workloads, moving SRAs alone would reduce the daily test time shortfall by only 17 hours.

If capacity demand is to be reduced to the available 84 hours per day,[6] some WRA testing will have to be moved from the shipboard VAST. Figure IV-2 is a frequency distribution of WRA test time demands that highlights the WRA selection alternatives. Thirteen items account for over a third of the daily test time. On the other hand, most items, due

---

[6] The performance results discussed in Chapter V indicate that priority repair can compensate for minor capacity overloads and maintain acceptable levels of performance. They suggest that if expected demand were reduced to about 90 hours per day, VAST would not create a severe performance constraint.

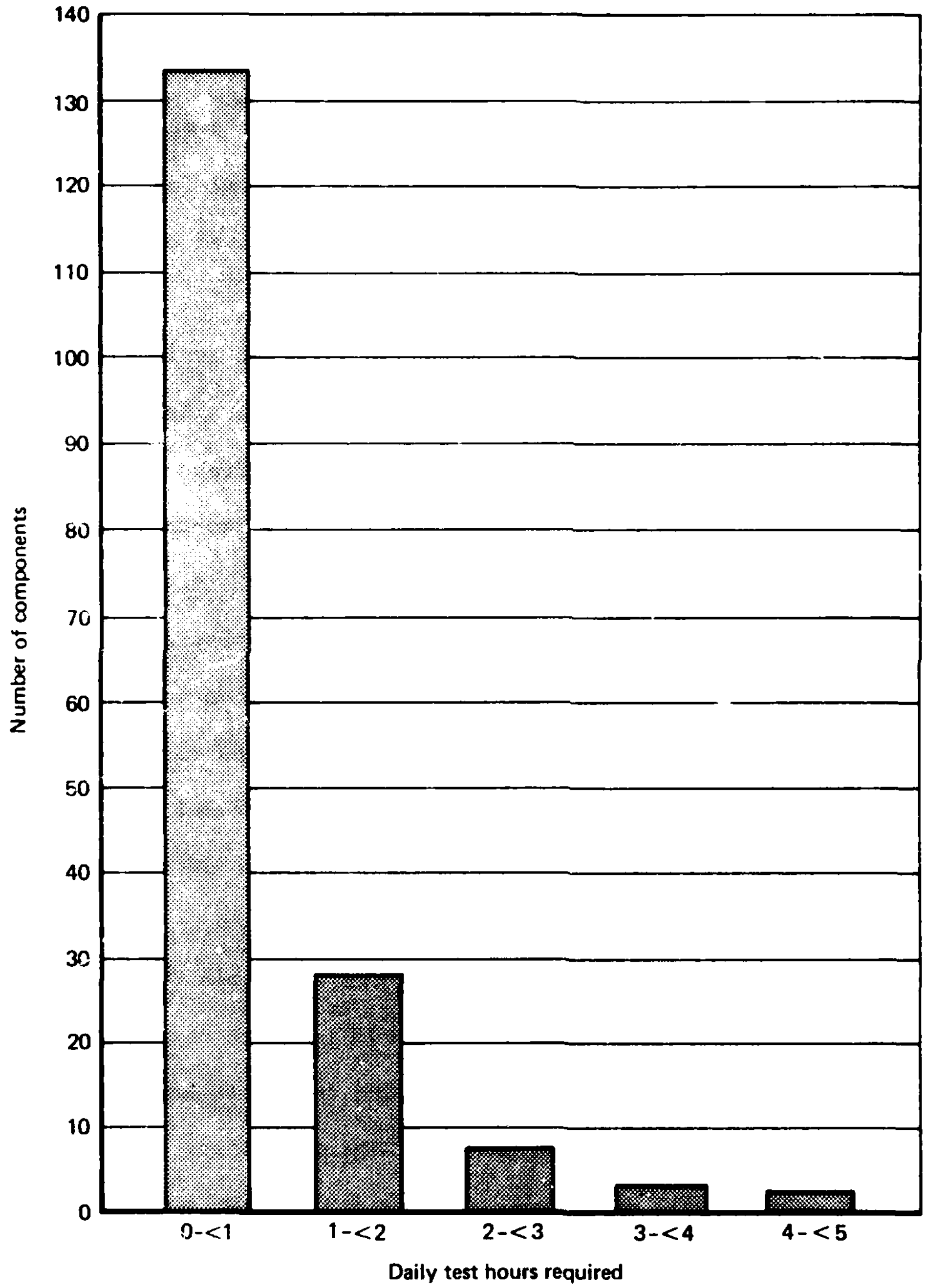

Fig. IV-2 — Distribution of daily test time demand: WRAs repaired on VAST to their demand rate, their test time, or a combination of the two, generate quite low daily test time requirements. The capacity shortfall that remains after SRAs are moved to other test equipment can be offset by moving either 10 high demand, or 126 low demand WRAs to other test equipment or ashore.

A third approach to item identification recognizes that an hour of VAST test capacity has a value that varies by item. The "marginal value of test time" can be defined as the increased pipeline cost of repairing a component ashore divided by daily test equipment capacity requirements. Figure IV-3 reveals that this computed value of test equipment capacity varies widely by component. Most components have a "marginal value of test time" of less than $100,000 per hour, but for some components an hour of test time is worth more than $4 million because of the high cost of filling the pipeline to a shore-based AIMD. If components were assigned to VAST so as to serve those with the highest marginal value of test time demand until the 84 hour capacity limit was reached, 354 of the 444 items currently assigned to VAST would be redirected to other test equipment or to shore-based AIMDs. The expected value of the increased pipeline cost associated with moving these components ashore for repair is $3.8 million.[7]

---

[7] Computed on the assumptions that: (1) no other shipboard test equipment can be configured to test these components; (2) the increase in repair pipeline would be 90 days--25 days O&ST plus 65 days retrograde; and (3) the full S-3A flying program must be supported. These costs would of course be less if more reasonable shipping times could be realized. For the reduced S-3A flying program mentioned earlier, 284 components would be moved, and the increased costs for a 90-day pipeline would be less than $1 million.

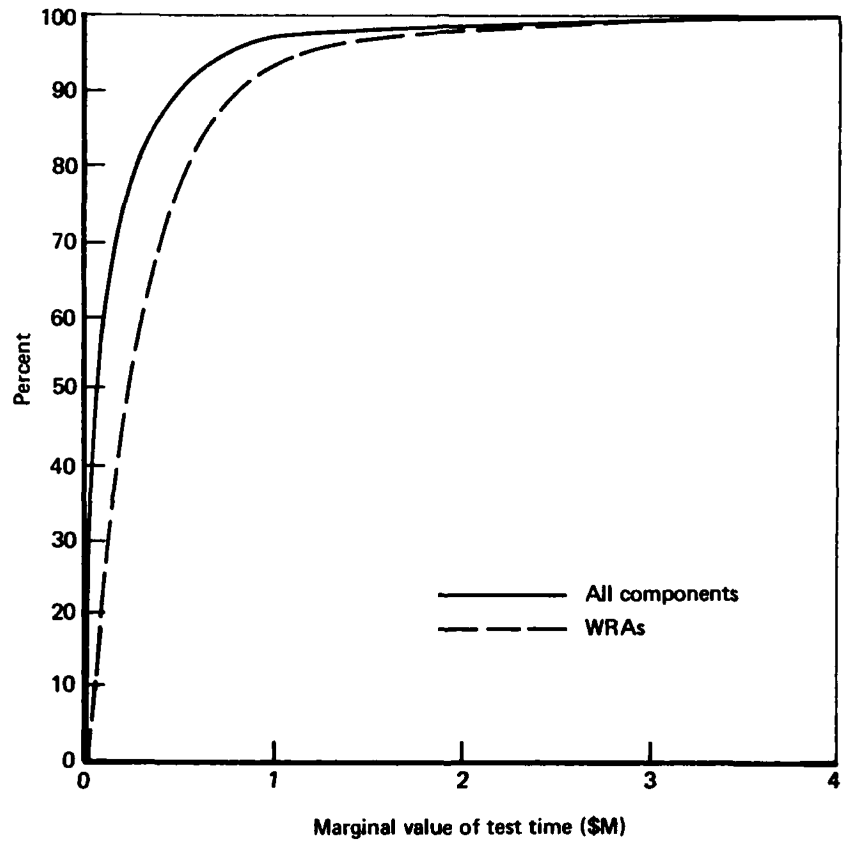

Fig. IV-3 — Distribution of components by their marginal value of test time

Finally, the capacity shortfall could be reduced by increasing the test capacity by increasing the number of VAST installations aboard the carrier. This alternative would require buying two to three additional VAST stations per carrier at a cost of over $10 million per ship. The above analysis indicates that it would be more economical to move some selected repair ashore than to increase the number of VAST stations on the ship. To the extent that excess VAST workload can be absorbed by other shipboard test equipments, the alternative of increasing VAST capacity looks even less attractive. Also, adding VAST capacity would exacerbate existing carrier space problems. Thus, increasing the number of VAST installations does not appear to be a desirable option.

The foregoing discussions of VAST capacity requirements are based on two scenarios: that planned for wartime, and the one used as a basis for spares requirements today. The percentage of VAST capacity required for these two scenarios, with and without SRA repair, is tabulated in Table IV-1. The number of items that would have to be moved, and their associated pipeline costs, are shown in Table IV-2. In addition to demonstrating the effects of these specific flying program and testing

Table IV-1

VAST CAPACITY REQUIREMENT
(Percent)

	S-3A Wartime Flying Program	
Items Tested	Programmed	Stockage Computations
WRAs and SRAs	160	132
WRAs only	140	114

alternatives, the tables indicate clearly that capacity demand and "unloading costs" are highly sensitive to scenario assumptions. How much WRA repair would have to be moved off the shipboard VAST to prevent backlogs from growing is thus a function of the scenario to be supported.

The CABAL study was not tasked (and lacked the information needed) to determine what constitutes a "reasonable" scenario. The scenarios were consistent with current Navy planning, but it is possible that organizational level maintenance constraints or combat attrition could limit generation of intermediate maintenance workloads. The study's findings, however, indicate that VAST capacity limitations suggest

Table IV-2

COMPONENTS AFFECTED AND COSTS OF ELIMINATING THE VAST CAPACITY SHORTFALL

Components Selected	All Components S-3A Flying Program				WRAs After All SRAs Moved S-3A Flying Program			
	Programmed		Stockage		Programmed		Stockage	
	N	$M	N	$M	N	$M	N	$M
Low test time demand	413	10.8	382	5.6	126	9.4	89	3.1
Lowest "marginal value of test time"	354	3.8	284	.9	85	3.4	46	.6
High test time demand	19	50.2	9	39.5	10	44.3	3	26.1

N: number of components moved.
$M: increased pipeline cost for a shore repair alternative, $ millions.

either logistics policy changes or degraded wartime capability in both the scenarios. Failure to relieve the capacity constraint by pursuing demand-reducing options may reduce test time demands because aircraft cannot meet their programmed flying hours due to parts shortages.

V. MAINTENANCE MANAGEMENT

Two potentially important aspects of AIMD/supply management, priority repair and AWP management, were not considered in the DRMS. AWP management is primarily a supply problem and is treated in the report describing the CABAL supply analysis [Ref. 3]. Priority repair, although it requires good visibility of supply status, is primarily an AIMD job control function and will be discussed here.

Because the AIMD is the primary source of supply for avionics reparables, a close working relationship between maintenance and supply management must be maintained. Existing policies that attempt to monitor the stock status of pool items and aircraft status so that critical items can be inducted for expedited repair (EXREP) demonstrate that the importance of priority repair is widely recognized within the Navy. The success of its implementation, however, seems to vary somewhat across carriers.

Priority repair is important because it can dramatically shorten repair times for critical items that are keeping aircraft down. As was discussed in the previous chapter, actual test time represents a very small fraction of total AIMD turnaround time. Priority repair decreases the administrative segments of turnaround time, particularly the part of repair time that is spent "awaiting maintenance" in the shop, and expedites delivery of critical component to stock and the flight line.

The key to employing this potentially very powerful tool is to identify the components that are most likely to degrade aircraft availability and give them first priority in repair scheduling decisions. The rules for scheduling EXREPs vary across carriers, but generally focus on items with backorders or those with a low "pool" quantity[1] on hand. Although this simple algorithm is sufficient for allocating repair capacity in peacetime, the higher intensity of wartime activity is likely to demand finer distinctions among priorities, particularly for a capacity-constrained repair process such as VAST.

A slightly more sophisticated algorithm that can better distinguish among priorities was developed during the CABAL analysis. This scheduling rule attempts to equalize the number of backorders (holes in aircraft) outstanding across components, or to equalize the number of days of stock on hand[2] if no backorders are outstanding. Thus, it is controlled by the stock position of each item, seeking to repair first the component with the largest number of backorders outstanding. It requires greater visibility of supply status than is currently used in repair scheduling.

The scheduling algorithm was employed in a finite server queuing formulation of the maintenance capacity allocation problem. The analysis assumed a continuous 90-day scenario in which all aircraft with VAST reparable items (E-2C, S-3A, F-14) flew at their full programmed rates. As noted in the previous section, this schedule generates repair

---

[1] The Navy's stockage requirements methodology identifies one part of the allowance for high velocity reparables--those having more than one repair per month--as the "pool" quantity. These assets are intended to cover the shipboard repair pipeline. Stockage requirements are further discussed in Ref. 3.

[2] The number of days of stock on hand is defined as the serviceable stock level divided by the Daily Demand Rate (DDR) for a component. The DDR is the product of component removals/flying hour and aircraft flying hours/day. The scheduling algorithm is discussed further in Appendix B.

requirements equal to 160 percent of VAST capacity. Nonetheless, even though the backlog outstanding at the end of the 90-day scenario was equivalent to 51 days of capacity, the maximum number of expected backorders for any one component was only two. The above includes those expected to be awaiting parts based on the analysis of indentured components discussed in Ref. 3.

The above result was achieved only by concentrating available repair on an increasingly small subset of components--those critical components for which there were backorders causing holes in aircraft. As is shown in Fig. V-1, only 5 percent of the 444 reparables assigned to VAST were being scheduled after day 60, and 20 percent were not tested at all during the 90-day scenario.

As might be expected, initial failures for which no stock was available were repaired, allowing a backlog of components with higher demand rates (and higher stock level) to develop. As serviceable stock levels were drawn down, it became increasingly likely that these high-demand components would create holes in aircraft, so their repair priority increased. The scheduling rule began to equate daily input to the repair process with daily output for these high-demand components. As shown in Table V-1, by day 90 the maximum serviceable stock on-hand for any component was 2.

The distribution of component test backlog by number of test hours required at day 30 and day 90 of the scenario is shown in Fig. V-2. By day 30 there are 218 reparable carcasses awaiting maintenance. Ten line items would individually require at least one full day of test time on a dedicated VAST; one of these components would alone tie up a VAST stand

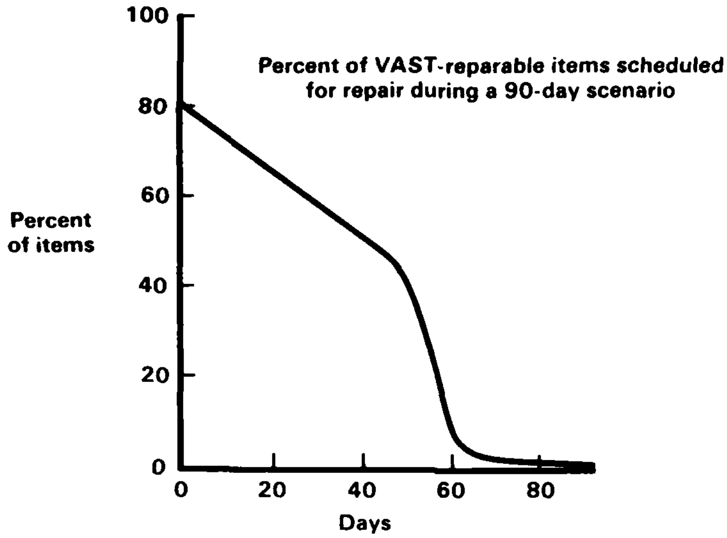

Fig. V-1—Priority repair scheduling

Table V-1

AUTHORIZED VERSUS SERVICEABLE STOCK LEVELS AT DAY 90

Serviceable Stock at Day 90	Authorized Stock Level						
	0	1	2	3	4	5	6
-2	1	--	--	--	--	--	--
-1	14	16	33	14	18	12	7
0	143	105	24	8	8	--	1
1	--	13	1	--	--	1	--
2	--	--	1	--	--	--	--
Total	158	134	59	21	26	13	8

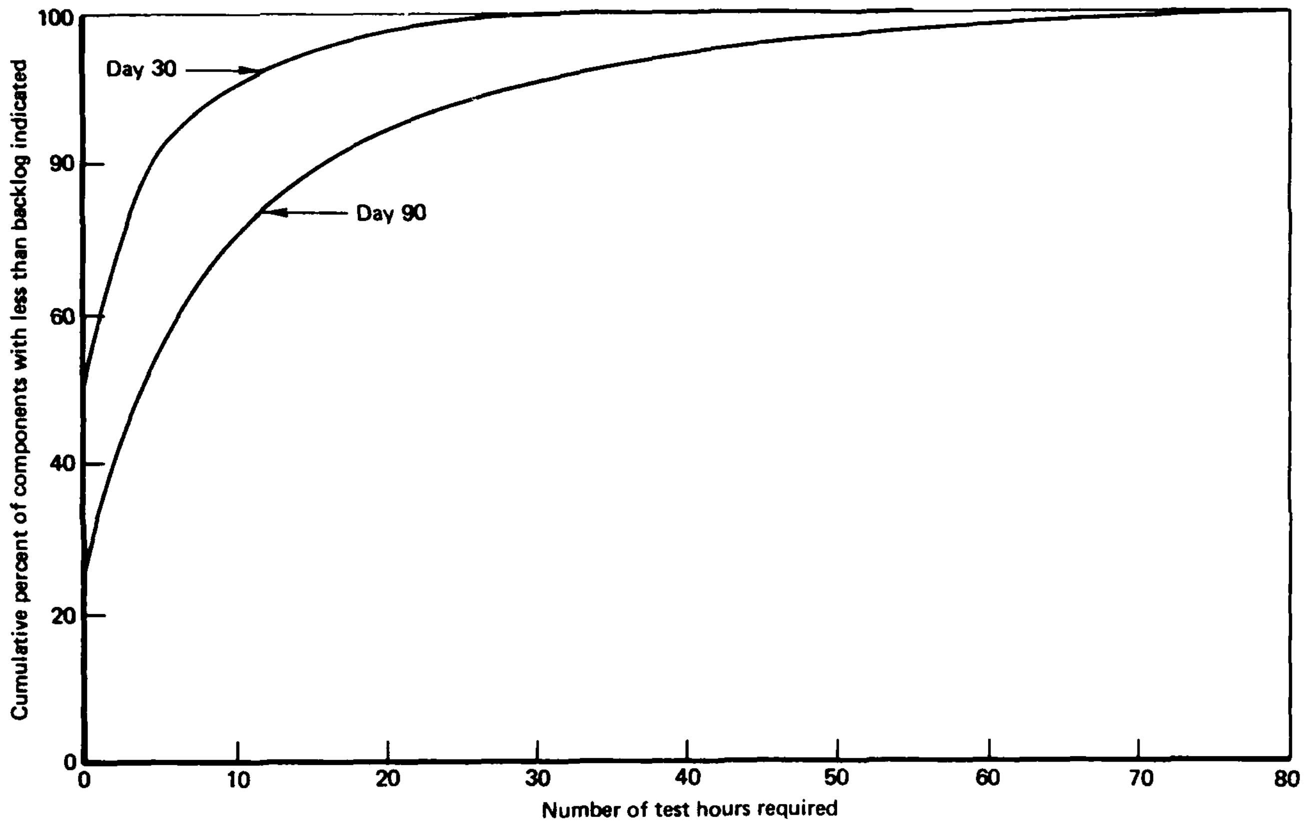

Fig. V-2—VAST backlog distribution at wartime flying rates for 2-1/2 days. Together they require the full capacity of a single stand for nearly 15 days.

By day 90, the situation has deteriorated markedly. The number of units awaiting maintenance has increased by over 300 since day 30, to a new total of 428. Three components could each tie up the carrier's four stands--84 hours of test capacity--for nearly a full day. The dollar value of stock tied up in the queue for these three items is over $3 million. In addition, there are 67 components with an awaiting maintenance backlog greater than one stand-day; they account for over 60 percent of the 51-day testing backlog projected at the end of the scenario.

Figures V-3 and V-4 contrast the effects of spares shortages on the operational availability of the S-3A and F-14A under the assumption that peacetime maintenance turnaround times can be maintained in wartime with an assumption based on: (1) the queuing analysis just described and (2) the expected results if there were no priority repair. The results show that wartime performance can be expected to deteriorate markedly from that based on projection of peacetime maintenance performance, but that priority repair can limit the degree of performance degradation.

As was noted above, priority repair is employed in peacetime to compensate for resource shortages. The turnaround times used for the peacetime projection include the effects of peacetime priority repair. Priority scheduling of VAST does improve performance somewhat during the early days of the scenario, but as the backlog and repair times grow, performance is increasingly affected. For this analysis only VAST is operating with priority repair and other components are being repaired

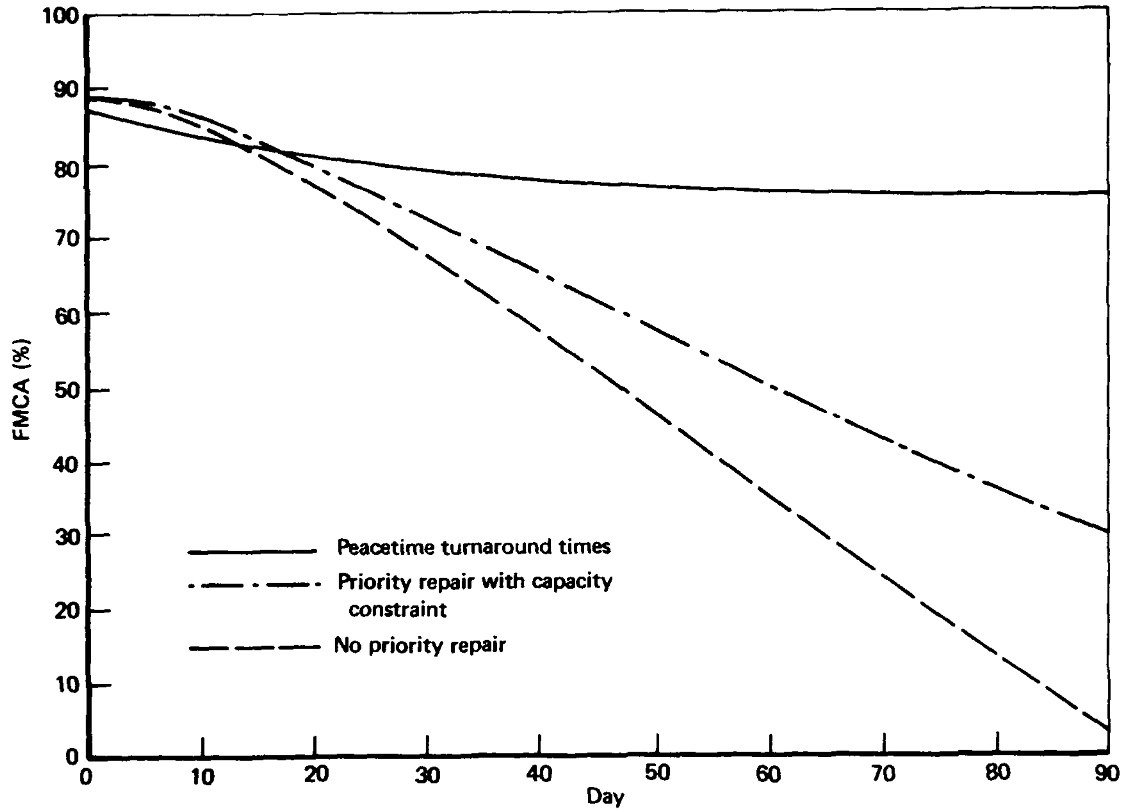

Fig. V-3—Effect of VAST limitations and priority repair:
S-3A with full cannibalization

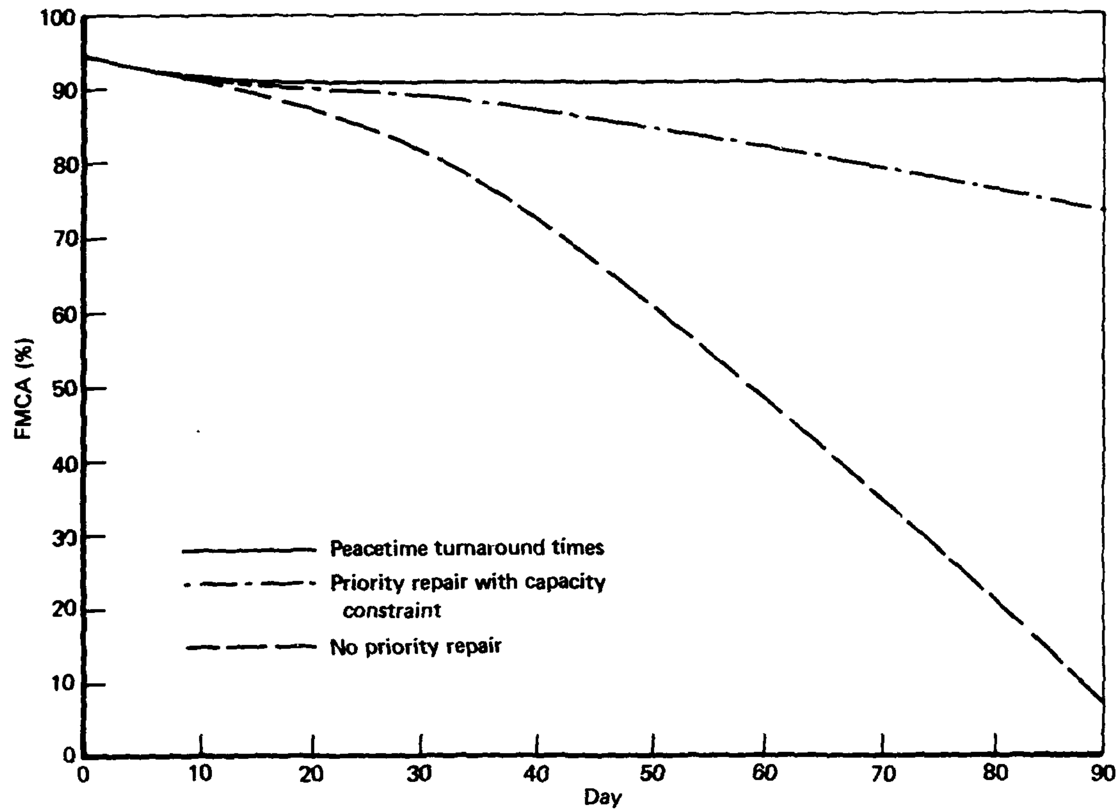

Fig. V-4—Effect of VAST limitations and priority repair: F-14A with full cannibalization

AD-A114 028   RAND CORP SANTA MONICA CA   F/G 15/5
CARRIER BASED AIR LOGISTICS STUDY: MAINTENANCE ANALYSIS.(U)
JAN 82 T F LIPPIATT, L B EMBRY, J SCHANK   N00014-80-C-0049
UNCLASSIFIED   RAND/N-1784-NAVY   NL

2 OF 2
AD A
114028

END
DATE
FILMED
05-82
DTIC

at the rates measured in peacetime. The figures also show that priority repair significantly improves performance over that which could be expected if there were no priority repair--even when VAST is overloaded.

The figures show that:

- o Performance late in the 90-day scenario is poor even under the assumption of full cannibalization. If there were no cannibalization, performance would be considerably worse.
- o Some action to relieve VAST capacity bottleneck must be taken or the VAST will create a severe constraint on operational performance.

Concerning the first point, Fig. V-5 shows the difference between expected FMCA with and without cannibalization. Both curves are based on the VAST queuing analysis described above. The E-2C experiences much more severe performance degradation under full cannibalization than either the F-14A or the S-3A.

Although cannibalization and priority repair do mitigate the effects of the VAST capacity shortfall, the small pool of E-2C aircraft available for cannibalization results in rapid deterioration on both the full- and no-cannibalization performance measures. The F-14A and S-3A fare better because they both have more aircraft available for cannibalization.

The small scale of squadrons such as the E-2C provided part of the motivation for the DRMS alternative [Ref. 9]. Cannibalization permits continued operation of E-2C aircraft by day 90 but the E-2C flying program can no longer be met. *Reducing the VAST capacity shortfall,*

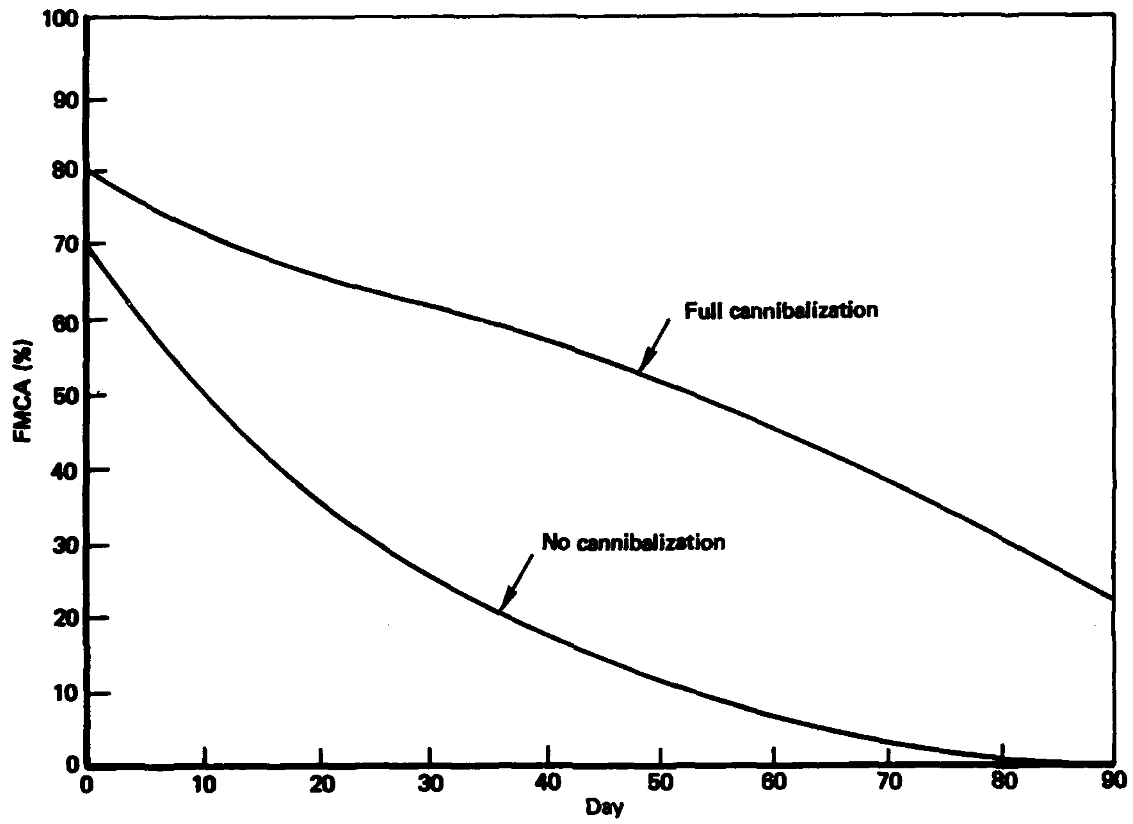

Fig. V-5—Contribution of cannibalization to performance:
E-2C with priority repair

which contributes to the performance degradation, could improve E-2C performance considerably.

The effects of some of the options for reducing the VAST capacity shortfall discussed in the previous chapter are shown in Figs. V-6 through V-8. They contrast expected FMCA with the current capacity constraint with that expected if: (1) all SRA repair were removed from the VAST or (2) two additional VAST stands were installed on the carrier. All three figures assume full cannibalization of WRAs.

Relaxing the VAST capacity constraint affects performance, particularly with priority repair. Performance with a reduced capacity shortfall and priority repair is uniformly better than that predicted based on extrapolation of peacetime maintenance performance (Figs. V-3 and V-4). This demonstrates both the potential value of priority repair and the potential for improving the effectiveness of priority repair scheduling through use of an improved scheduling algorithm.

The performance improvements resulting from increasing the VAST test capacity supply could also be realized by decreasing capacity demand. Adding two VASTs with an average availability of 21 hours per day would almost eliminate the capacity shortfall; demand would be 107 percent of the available supply.

With the reduced S-3A flying program discussed in Chapter IV, moving SRAs off VAST alone reduces capacity demand sufficiently so that priority repair can compensate for the remaining capacity shortfall. Figure V-8 shows that this compensation through scheduling, complemented by cannibalization, overcomes the severe degradation of E-2C performance shown in Fig. V-5.

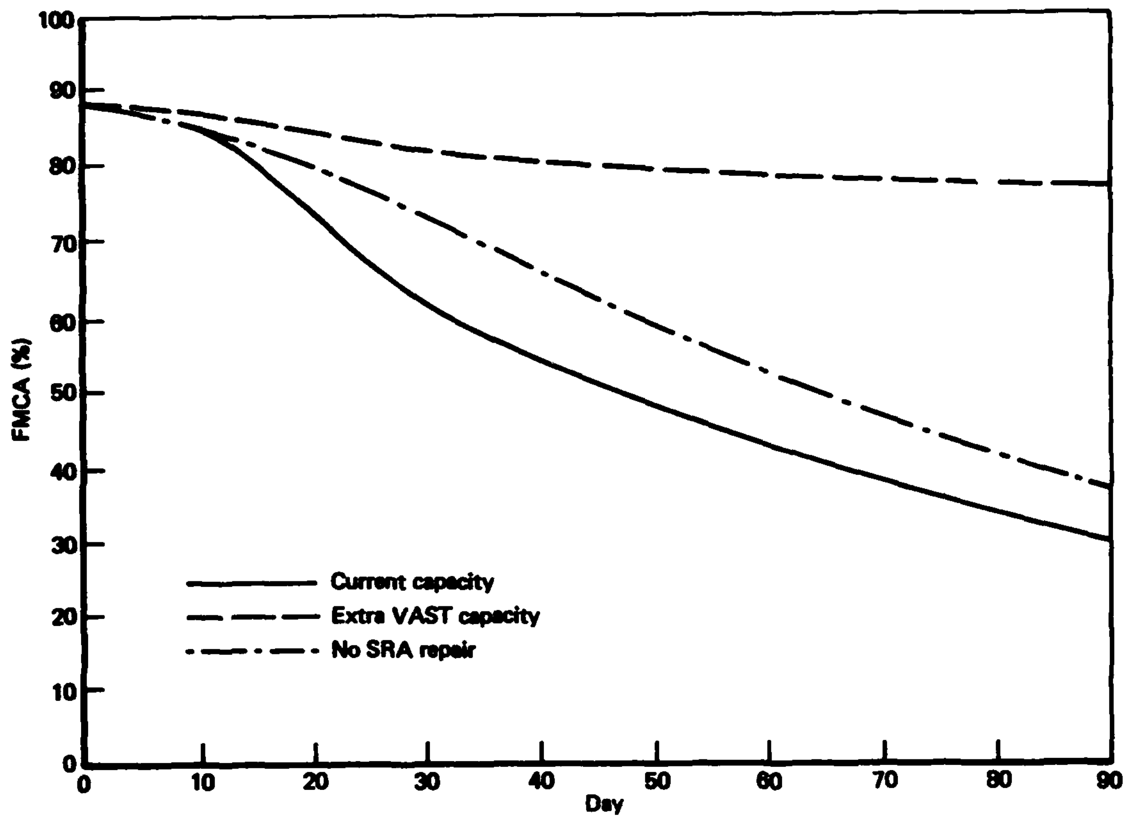

Fig. V-6—Performance effects of reducing the VAST capacity shortfall: S-3A with full cannibalization

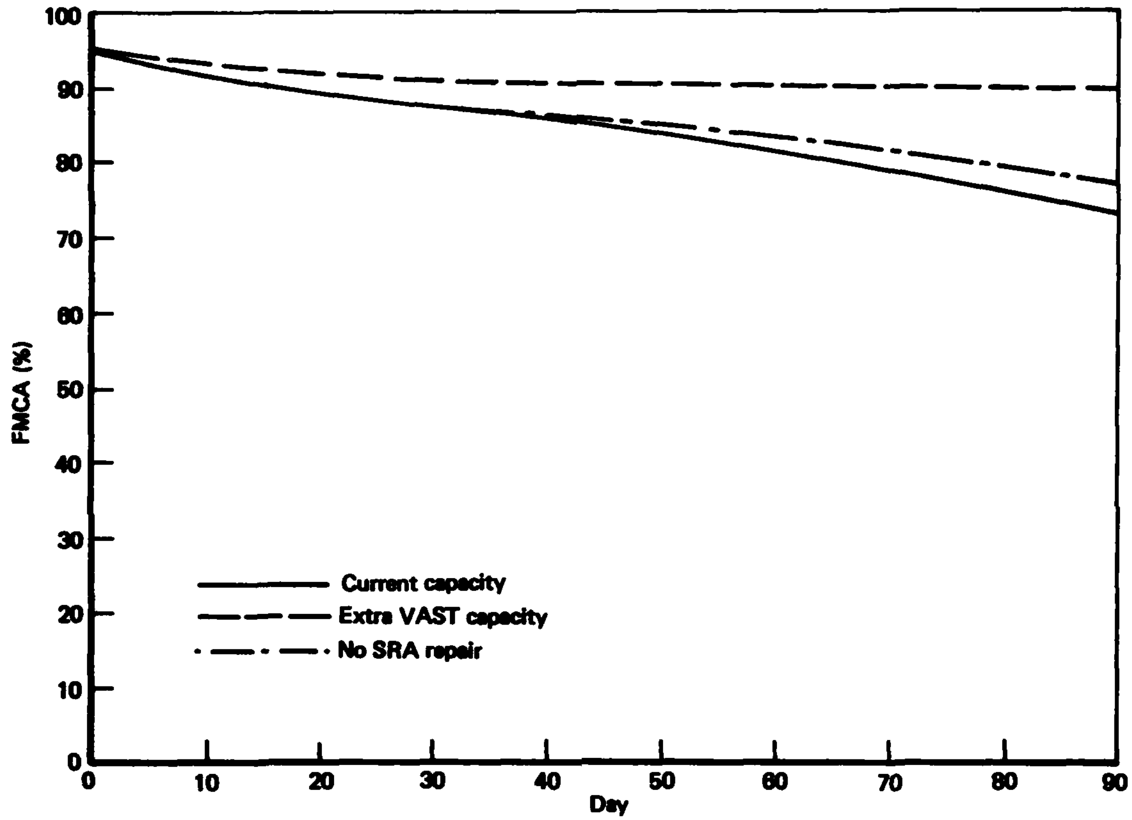

Fig. V-7—Performance effects of reducing the VAST capacity shortfall: F-14A with full cannibalization

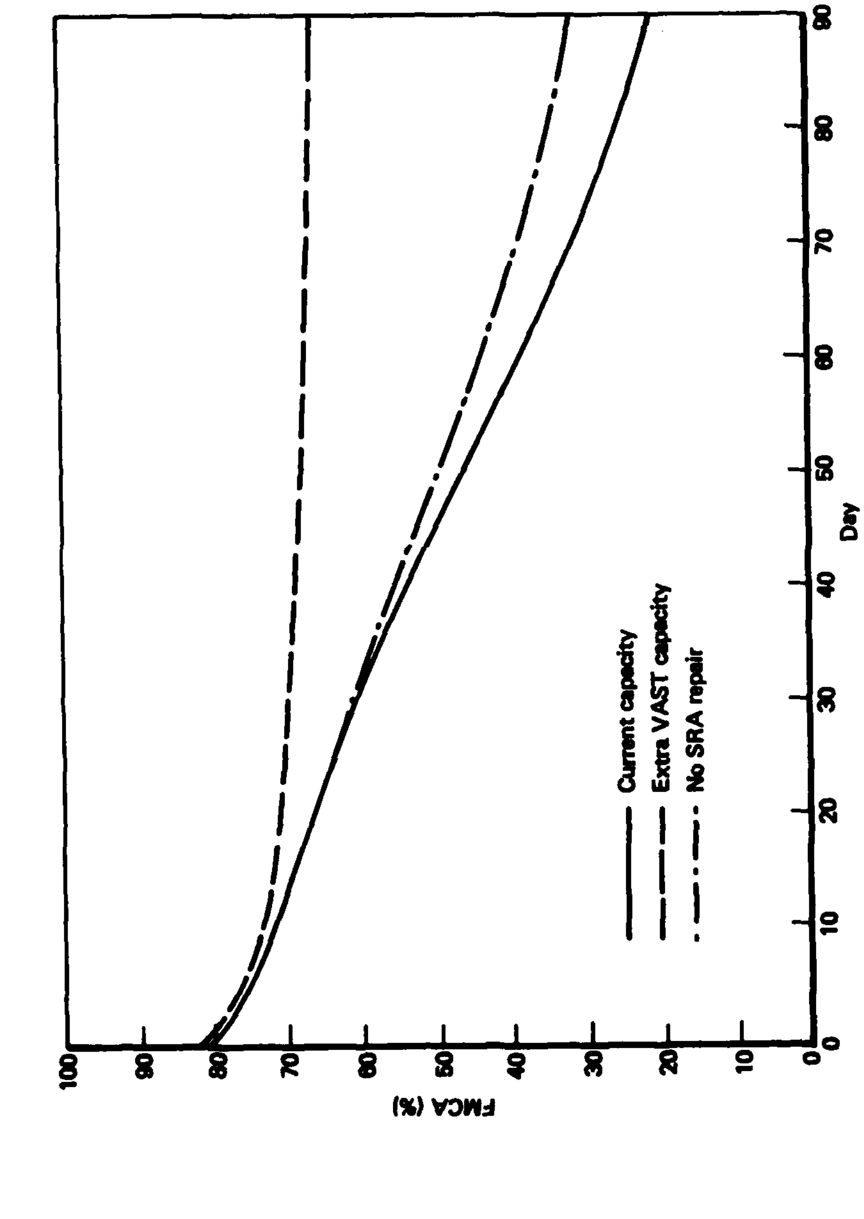

Fig. V-8—Performance effects of reducing the VAST capacity shortfall;
E-2C with full cannibalization

Table V-2 shows the number of components that would have to be moved off VAST to yield 107 percent utilization with the four existing VAST stands. The components to be moved were selected using the marginal value of test time criterion discussed in the previous chapter. A few high cost SRAs have a higher marginal value of test time than some low demand and/or low cost WRAs. SRAs should probably be removed, however, before applying the criterion to identify WRA move candidates because WRAs have a direct, and SRAs only an indirect, effect on aircraft material condition (FMCA).

This analysis focused on VAST because it was the only repair resource that appeared virtually certain to impose a constraint on aircraft availability and operational performance. Manpower and test equipment do not appear to pose problems in work centers other than the VAST shop, and the analysis has assumed that the levels of spares, manpower, and test equipment developed through the requirements process

Table V-2

COMPONENTS MOVED FROM VAST TO REDUCE DEMAND
TO 107 PERCENT OF CAPACITY

	S-3A Flying Program			
	Full Scenario		Reduced Scenario	
Components Considered	No.	$M	No.	$M
WRAs and SRAs	337	2.8	257	.5
WRAs only	73	2.2	30	.2

are available. In the real world, spot shortages of resources will exist. The results of the analysis performed for VAST can be generalized: priority repair can be used to compensate for other resource shortages, particularly manpower or spare parts, _if_ maintenance management uses information concerning supply stock position and aircraft availability as the bases for its scheduling decisions.

VI. SUMMARY AND RECOMMENDATIONS

Foregoing chapters have discussed maintenance resources. Maintenance, however, is only one element of the logistics system; supply and transportation resources and policies interact with maintenance to determine aircraft availability. The maintenance analysis reported here, like that on supply and transportation [Ref. 3], emanated from a cross-functional analysis that addressed the logistics system as a whole.

The following findings and recommendations concern maintenance policies and resources. The combined effects of all relevant functions are outlined in the CABAL Integrated Summary [Ref. 5]. Although the recommendations presented here should lead to improvements in logistics system performance and management, they should be considered in the context of the broader system view given in the integrated summary report.

MANPOWER

Current manpower requirements are based on peacetime workloads. Increases in workload associated with wartime acceleration of the flying program will overload many avionics work centers.

A manpower requirement based on the total AIMD wartime workload generated from all carrier aircraft would be no larger than the current ACM-02 requirement. The mix of skills, however, would differ and would support the wartime workloads.

No manpower savings would result from consolidating carrier workloads at shore-based AIMDs. Projected manpower utilization rates on board the carrier under the AIMD manning alternative exceed 90 percent for all avionics work centers.

Based on these findings, it is recommended that the Navy base manpower requirements on projected wartime AIMD workloads rather than on peacetime squadron workload. Revisions in personnel management would require Navy policy decisions. Limited analysis favors an alternative that assigns personnel to the AIMD rather than to individual aircraft squadrons.

TEST EQUIPMENT

VAST does not have sufficient capacity to support the workload generated by a sustained wartime flying program. The effect of this capacity limitation is scenario-dependent. With well-managed priority repair and cannibalization, the VAST can support the flying program for limited periods without severe degradation in aircraft material condition. For longer, sustained scenarios, aircraft availability will decrease dramatically as the backlog increases.

Most other test equipments have low projected wartime utilization. However, no significant cost savings would be realized by centralizing requirements for these equipments since they represent a sunk cost.

These findings suggest that the Navy should explore options to reduce the projected VAST capacity shortfall. The magnitude of the VAST problem is scenario-dependent and careful thought should be given to scenario requirements before deciding on ways to reduce the VAST backlog. For example, a reduction in the S-3A wartime flying from programmed rates to those rates used in computing stockage requirements would reduce the VAST capacity requirement from 160 percent to 132 percent. One alternative to reduce the backlog would be to move all technically feasible SRA repair to other shipboard test equipment or to move it to VAST stations at shore-based facilities with excess wartime capacity. A combination of both options is likely to be the least expensive, but if all VAST SRA repair were moved ashore the cost of additional spare parts to cover the transportation pipelines would be about $1.2 million per carrier at the full wartime flying program. With the reduced S-3A flying requirements and the shore repair option, the additional stockage cost would be about $1 million per carrier and the VAST capacity requirement would be reduced from 160 percent to 114 percent.

None of the alternatives discussed here bring the VAST capacity requirement down to 100 percent of capacity. To do so would require moving some WRA repair off VAST in addition to all SRA repair, or buying three additional VAST stations. Any reduction in workload, however, will allow for longer periods of sustainability and therefore decisions on how much reduction is required depends heavily on the scenario to be supported.

The Navy should also <u>maintain test equipment availability data</u> to support the LOR decision process. Since these data are not currently maintained, the Navy may assume that test equipments are available for a large fraction (or all) of their installed time. Such an assumption could have contributed to the current VAST capacity problem. Collecting more accurate data need not imply new data system or routine reporting requirements; the data need can be satisfied by conducting periodic studies of equipment status over relatively short periods of time.

Finally, the Navy should explicitly consider a shore-based repair option for future systems. Purchasing the stock needed to fill transportation pipelines may be less expensive than buying unique, low utilization test equipments for all of the carriers. Using shore-based Intermediate Maintenance Activities (IMAs) as an option can and should be considered explicitly during the Level of Repair (LOR) decision process.

MAINTENANCE MANAGEMENT

Local priority repair is an extremely powerful tool that can compensate over limited time horizons for a variety of resource shortages. It can, in effect, shorten repair times for critical items to maintain maximum aircraft availability in the face of short-term resource shortages. Maintenance use of a scheduling rule that explicitly considers the stock position of each item repaired can concentrate repair on those components most likely to degrade aircraft availability. Hence it is recommended that the Navy support priority repair management explicitly in its continuing development of maintenance management support systems such as NALCOMIS [Ref. 8]. Such support would require integrating or interfacing supply and maintenance data to permit the supply stock position to be used as the basis for maintenance scheduling decisions.

Appendix A

DETAILED MANPOWER DATA AND ANALYSES

This Appendix presents the data used for the various analyses discussed in the body of the report. The data are shown in a set of tables, each of which is described below.

ACM-02 AVIONICS WORKLOAD

This table shows the various aircraft NEC workloads in the avionics work centers. The workloads were calculated from the most recent documentation of the ACM-02 model (dated March 30, 1979) by manipulating the model's appropriate B values, CV Z matrix, and NEC percentages. The data are shown for the deckload of the USS CONSTELLATION. The numbers of aircraft on the CONSTELLATION and the flying hours per aircraft per month for the timeframe of the ACM-02 data are:

Aircraft	Number	FH/AC/month
A-6E	10	29.9
A-7E	24*	40.2
E-2C	4	43.2
EA-6B	4	38.0
F-14A	24*	25.0
KA-6D	4	30.4
S-3A	10	34.2
SH-3H	6	42.5

*Two squadrons

Component workload that does not require a specific NEC is accumulated for each aircraft and designated a dummy NEC in each work center. These dummy NECs are:

AT2500	(COMM/NV)
AE2600	(ELEC/INST)
AQ2700	(FIRE CONTROL)
AT2800	(RADAR/ECM)
AE2900	(SACE/INS)
AP3000	(VAST)*
AX3100	(ASW)
AP3400	(MODULE REPAIR)

*The VAST workload requires an AP06652 or 6659.

Table A-1 represents the base case workload file for the AIMD of the CONSTELLATION.

Table A-1

ACM-02 AVIONICS WORKLOAD:
CONSTELLATION

COMM/NV SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-6E	AT2500	12.30
	AT6604	36.55
	AT6605	9.27
	AT6606	25.20
	AT6607	2.78
	AT6608	0.14
	AT6609	2.90
	AT6611	0.43
	AT6612	2.05
	AT6613	0.48
A-7E	AT2500	16.68
	AT6604	1.18
	AT6605	6.37
	AT6607	4.58
	AT6608	0.36
	AT6609	25.71
	AT6611	53.34
	AT6612	35.03
	AT6617	35.55
E-2C	AT2500	9.85
	AT6605	1.03
	AT6606	4.72
	AT6607	0.27
	AT6609	3.62
	AT6611	10.99
	AT6612	4.82
EA-6B	AT2500	8.29
	AT6604	37.02
	AT6605	3.08
	AT6606	14.03
	AT6607	1.36
	AT6609	2.12
	AT6611	12.26
	AT6612	0.73
	AT6633	0.01
F-14A	AT2500	22.44
	AT6605	3.63
	AT6607	0.04
	AT6609	18.54

Table A-1 (Continued)

COMM/NV SHOP (CONT'D)

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
F-14A (CONT'D)	AT6611	16.92
	AT6612	5.43
KA-6D	AT2500	2.43
	AT6604	26.72
	AT6605	7.00
	AT6606	7.14
	AT6607	0.41
	AT6608	4.79
	AT6609	0.83
	AT6611	3.23
	AT6612	0.12
	AT6613	0.03
S-3A	AT2500	6.06
	AT6605	0.27
	AT6607	0.76
	AT6608	0.10
	AT6609	8.56
	AT6611	5.11
	AT6612	2.24
SH-3H	AT2500	6.53
	AT6604	0.01
	AT6605	3.50
	AT6606	3.31
	AT6608	3.72
	AT6609	4.32
	AT6611	10.89
	AT6612	2.74

ELEC/INST SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-6E	AE2600	91.78
	AE7109	0.01
	AE7133	3.11
A-7E	AE2600	108.05
	AE7109	0.28
	AE7133	10.48

Table A-1 (Continued)

ELEC/INST SHOP (CONT'D)

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-7E (CONT'D)	AE7144	0.03
	AE7171	21.96
E-2C	AE2600	8.42
	AE7105	2.29
EA-6B	AE2600	32.85
	AE7105	10.22
	AE7109	0.13
F-14A	AE2600	53.69
	AE7136	0.09
	AE7144	0.12
KA-6D	AE2600	42.07
	AE7133	0.93
S-3A	AE2600	13.48
	AE7133	0.13
	AE7144	0.02
	AE7175	4.37
SH-3H	AE2600	46.99
	AE7105	0.97
	AE7109	0.38
	AE7136	0.02
	AE7144	14.92

FIRE CONTROL SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-6E	AQ2700	0.10
A-7E	AQ$$$$	0.33
	AQ****	0.05
	AQ2700	4.71
	AQ7921	34.45
	AQ7975	96.69
	AQ7976	24.03
	AT6603	12.34
F-14A	AQ$$$$	259.48

Table A-1 (Continued)

FIRE CONTROL SHOP (CONT'D)

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
F-14A (CONT'D)	AQ2700	107.11
	AQ7921	0.07
	AQ7925	0.04
KA-6D	AQ2700	0.73
	AQ7975	0.87

RADAR/ECM SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-6E	AT2800	9.14
	AT6639	13.53
	AT6641	14.88
	AT6643	0.14
	AT6666	0.01
A-7E	AT2800	24.15
	AT6639	21.55
	AT6641	26.39
	AT6643	0.31
	AT6644	0.24
	AT6646	0.26
	AT6647	0.01
E-2C	AT2800	12.93
	AT6616	39.23
	AT6646	2.44
EA-6B	AT2800	40.95
	AT6641	0.30
	AT6643	16.73
	AT6647	172.22
	AT6666	43.30
F-14A	AT2800	28.68
	AT6639	24.45
	AT6643	50.97
KA-6D	AT2800	1.99
	AT6639	4.89
	AT6641	3.29

Table A-1 (Continued)

RADAR/ECM SHOP (CONT'D)

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
KA-6D (CONT'D)	AT6643	0.03
S-3A	AT2800	42.00

SACE/INS SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-6E	AE2900	66.86
	AE7112	23.17
	AE7116	0.02
	AE7132	8.85
	AE7149	18.12
	AQ7953	40.61
	AQ7954	10.14
	AQ7963	7.14
	AQ7964	33.79
A-7E	AE2900	6.02
	AE7112	0.13
	AE7116	162.31
	AE7128	46.63
	AE7149	0.19
	AQ7964	0.02
E-2C	AE2900	24.79
	AE7132	3.88
	AE7149	10.57
	AT6623	1.01
	AT6626	0.35
EA-6B	AE2900	18.03
	AE7132	4.13
	AQ7953	0.22
	AQ7963	36.45
	AQ7964	5.37
F-14A	AE2900	53.71
	AE7149	43.89
KA-6D	AE2900	6.54
	AE7112	1.16

Table A-1 (Continued)

SACE/INS SHOP (CONT'D)

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
KA-6D (CONT'D)	AE7116	0.33
	AE7128	0.01
	AE7132	5.94
	AQ7954	0.02
	AQ7964	8.30
S-3A	AE2900	35.38
	AE7149	37.92

VAST SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
E-2C	AP3000	74.60
F-14A	AP3000	324.50
S-3A	AP3000	219.00

ASW SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
S-3A	AX3100	25.82
	AX6526	0.35
	AX6527	0.03
SH-3H	AX3100	3.37
	AX6522	1.18
	AX6526	1.70
	AX6527	7.09
	AX6529	1.51
	AX6564	0.53

MODULE REPAIR SHOP

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
A-6E	AP3400	75.60
A-7E	AP3400	22.10

Table A-1 (Continued)

MODULE REPAIR SHOP (CONT'D)

AIRCRAFT	NEC	WKLY WORKLOAD (HOURS)
E-2C	AP3400	16.00
EA-6B	AP3400	47.50
F-14A	AP3400	170.80
KA-6D	AP3400	11.90
S-3A	AP3400	62.30
SH-3H	AP3400	2.85

ACM-02 AVIONICS TAD MANPOWER

Table A-2 presents the TAD manpower requirements from the ACM-02 model. These values are used in the various aircraft SQMDs. The values were obtained from the ACM-02 model group at NAVMMACLANT.

Table A-2

ACM-02 AVIONICS TAD MANPOWER:

CONSTELLATION

Shop	Aircraft: EA-6B	A-6E/KA-6D	A-7E	E-2C	F-14A	S-3A	SH-3H
COMM/NAV AT (35)	6605 6604/6609 6606/6612 6607/6611	6608 6609 6604/6611 6605/6607 6606/6612	6605 6609 6612 6617 6607/6611 (2 each)	6605 6606 6607/6611 6609/6612 6633/6646	6609 6605/6612 6607/6611 (2 each)	6607/6611 6609/6612	6605/6608 6606/6611 6609/6612
ELEC/INST AE (10)	7105	7133 AE -	7171 (2)	7105	AE - (2)	7175	7105/7144
FIRE CONTROL AQ (18)			7975 7976 7921/7923 (2 each)		7984 7988 7989 7984/7988 7985/7986 7991/7992 (2 each)		
RADAR/ECM AT (28)	6638 6643 6644 6647 (2) 6648 (2) 6666 6667 6674/6675 (3)	6639 6641/6643	6603 6639 6641/6643 (2 each)	6616 6671	6639 6643 (2 each)	6615 AT -	

Table A-2 (cont.)

	Aircraft						
Shop	EA-6B	A-6E/KA-6D	A-7E	E-2C	F-14A	S-3A	SH-3H
SACE/INS	AE7132	AT6651	AE7128	AT6631	AE7149 (2)	AE7149	
	AQ7963	AT6655	AE7116/7133	AT6683			
(21)	AQ7964	AE7112	(2 each)	AE7132			
		AE7132		AE7149/7196			
		AQ7953					
		AQ7954					
		AQ7964					
VAST			6652 (2)	6652 (2)	6652 (4)	6652 (5)	
APO				6659 (2)	6659 (2)	6659 (4)	
(21)							
ASW						6614	6522/6564
AX						6526	6526/6527
(5)							6527/6529
MOD REPAIR	7955	6683					
APO	7173	7173			7173 (2)	6619 (2)	
(10)		7955 (2)					

PEACETIME/WARTIME EXERCISE

Table A-3 contains the data used for the workload versus flying program analysis described in Chapter III. It shows the effects on manpower of linearly escalating the ACM-02 workloads to a wartime flying program. For each avionics work center, the peacetime hours and manpower columns represent the ACM-02 data contained in Tables A-1 and A-2. For each billet identified in Table A-2, the appropriate workload from Table A-1 is shown. These peacetime ACM-02 workloads were multipled by a factor to obtain the wartime hours shown in Table A-3. The factor for each aircraft is the wartime flying hours per aircraft per month from the CABAL scenario document divided by the peacetime flying hours of the ACM-02 data base. Wartime manpower was then determined by dividing the resulting hours by an availability of 60 hours per week. The fractional manpower cutoff tables in the ACM-02 documentation were used to determine the appropriate manpower requirements.

Certain NECs in Table A-2 have no corresponding workload in Table A-1, primarily because the NECs are relatively new and no historical values were available from 3M data. For these NECs it was assumed that the wartime manpower requirement was equal to the ACM-02 manpower requirement. This assumption may underestimate the actual manpower required in wartime.

Table A-3

PEACETIME/WARTIME EXERCISE:

CONSTELLATION

COMM/NAV SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-6E/KA-6D	6604/6611	66.9	1	125.4	2
	6605/6607	19.5	1	36.3	1
	6606/6612	34.5	1	63.4	1
	6608	4.9	1	9.6	1
	6609	3.7	1	6.8	1
	any	15.2	0	28.0	0
	TOTAL	144.8	5	269.5	6
A-7E	6607/6611	57.9	2	93.8	2
	6609	25.7	2	41.6	2
	6612	35.0	2	56.7	2
	6617	35.6	2	57.7	2
	6605	6.4	2	10.4	2
	any	18.2	0	29.5	0
	TOTAL	178.8	10	289.7	10
E-2C	6605	1.0	1	1.5	1
	6606	4.7	1	7.2	1
	6607/6611	11.3	1	17.4	1
	6609/6612	8.4	1	12.9	1
	6633/6646	0	1	0	1
	any	9.9	0	15.2	0
	TOTAL	35.3	5	54.2	5
EA-6B	6605	3.1	1	4.4	1
	6606/6612	14.8	1	21.2	1
	6604/6609	39.1	1	55.9	1
	6611/6607	13.6	1	19.4	1
	any	8.3	0	11.9	0
	TOTAL	78.9	4	112.8	4
F-14A	6609	18.5	2	39.7	2
	6605/6612	9.1	2	19.4	2
	6607/6611	17.0	2	36.3	2
	any	22.4	0	48.0	0
	TOTAL	67.0	6	143.4	6

Table A-3 (cont.)

(COMM/NAV SHOP cont.)

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
S-3A	6609/6612	10.8	1	39.4	1
	6607/6611	5.9	1	21.5	1
	any	6.4	0	23.4	0
	TOTAL	23.1	2	84.3	2
SH-3H	6605/6608	7.2	1	10.0	1
	6606/6611	10.9	1	15.1	1
	6609/6612	7.1	1	9.8	1
	any	9.9	0	13.7	0
	TOTAL	35.1	3	48.6	3

Table A-3 (cont.)

ELEC/INST SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-6E/KA-6D	7133	4.0	1	7.4	1
	any	133.9	1	248.2	3
	TOTAL	137.9	2	255.6	4
A-7E	7171	22.0	2	35.6	2
	any	118.8	0	192.5	2
	TOTAL	140.8	2	228.1	4
E-2C	7105	2.3	1	3.5	1
	any	8.4	0	12.9	0
	TOTAL	10.7	1	16.4	1
EA-6B	7105	10.2	1	14.6	1
	any	33.0	0	47.2	0
	TOTAL	43.2	1	61.8	1
F-14A	any	53.9	2	115.4	2
	TOTAL	53.9	2	115.4	2
S-3A	7175	4.4	1	16.1	1
	any	13.6	0	49.6	1
	TOTAL	18.0	1	65.7	2
SH-3H	7105/7144	15.9	1	22.1	1
	any	47.4	0	65.9	1
	TOTAL	63.3	1	88.0	2

Table A-3 (cont.)

FIRE CONTROL SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-7E	7975	96.7	2	156.7	4
	7976	24.0	2	38.9	2
	7921/7923	34.5	2	55.9	2
	any	5.1	0	8.3	0
	TOTAL	160.3	6	259.8	8
F-14A	TOTAL	366.7	12	784.7	14

Table A-3 (cont.)

RADAR/ECM SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-6E/KA-6D	6639	18.4	1	34.0	1
	6641/6643	18.3	1	33.7	1
	any	11.1	0	20.4	0
	TOTAL	47.8	2	88.1	2
A-7E	6603	12.3	2	20.0	2
	6639	21.6	2	35.0	2
	6641/6643	26.7	2	43.3	2
	any	24.7	0	40.0	0
	TOTAL	85.3	6	138.3	6
E-2C	6616	39.2	1	60.4	1
	6671	0	1	0	1
	any	15.4	0	23.7	1
	TOTAL	54.6	2	84.1	3
EA-6B	6674/6675	0	3	0	3
	6667	0	1	0	1
	6647	172.2	2	246.2	4
	6638	0	1	0	1
	6648	0	2	0	2
	6666	43.3	1	61.9	1
	6643	16.7	1	23.9	1
	6644	0	1	0	1
	any	41.3	0	59.1	1
	TOTAL	273.5	12	391.1	15
F-14A	6639	24.5	2	52.3	2
	6643	51.0	2	109.1	2
	any	28.7	0	61.4	0
	TOTAL	104.2	4	222.8	4
S-3A	6615	0	1	0	1
	any	42.0	1	153.3	3
	TOTAL	42.0	2	153.3	4

Table A-3 (cont.)

SACE/INS SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-6E/KA-6D	7112	24.33	1	44.2	1
	7132	14.8	1	27.6	1
	7953	40.6	1	73.5	2
	7954	10.2	1	18.4	1
	7964	42.1	1	77.3	2
	6651	0	1	0	1
	6655	0	1	0	1
	any	99.0	0	180.2	0
	TOTAL	231.0	7	421.2	9
A-7E	7116/7133	162.3	2	262.9	6
	7128	46.6	2	75.5	2
	any	6.4	0	10.4	0
	TOTAL	215.3	4	348.8	8
E-2C	7149/7196	10.6	1	16.3	1
	7132	3.9	1	6.0	1
	6683	0	1	0	1
	6631	0	1	0	1
	any	26.2	0	40.3	0
	TOTAL	40.7	4	62.6	4
EA-6B	7963	36.5	1	52.2	1
	7964	5.4	1	7.7	1
	7132	4.1	1	5.9	1
	any	18.3	0	26.2	0
	TOTAL	64.3	3	92.0	3
F-14A	7149	43.9	2	114.9	2
	any	53.7	0	93.9	2
	TOTAL	97.6	2	208.8	4
S-3A	7149	37.9	1	138.3	3
	any	35.4	0	129.2	2
	TOTAL	73.3	1	267.5	5

Table A-3 (cont.)

VAST SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-7E	6652	0	2	0	2
E-2C	6652/6659	74.6	4	114.9	4
F-14A	6652/6659	324.5	6	694.4	12
S-3A	6652/6659	219.0	9	799.4	13

Table A-3 (cont.)

ASW SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
S-3A	6526	.4	1	1.3	1
	6614	0	1	0	1
	any	25.9	0	94.4	1
	TOTAL	26.3	2	95.7	3
SH-3H	6527/6529	8.6	1	12.0	1
	6526	1.7	1	2.4	1
	6564/6522	1.7	1	2.5	1
	any	3.4	0	4.7	0
	TOTAL	15.4	3	21.6	3

Table A-3 (cont.)

MODULE REPAIR SHOP

Aircraft	NECs	Peace Hours	Peace Men	War Hours	War Men
A-6E/KA-6D		87.5	4	160.0	4
A-7E		22.1	0	75.5	0
E-2C		16.0	0	24.6	0
EA-6B		47.5	2	67.9	2
F-14A		170.8	2	365.5	6
S-3A		62.3	2	227.4	4
SH-3H		2.9	0	4.0	0
	TOTAL	409.1	10	924.9	16

AVIONICS NEC HOURS BY SHOP

Table A-4 contains the data used for the AIMD manpower analysis discussed in Chapter IV. The table shows the total workload for a given NEC in each of the avionics work centers. The peacetime workload represents the summation across all aircraft of the workloads shown in Table A-1. The peacetime manpower is a summary of the values in Table A-2. The wartime workloads are determined by multiplying the individual aircraft workloads by the aircraft's wartime/peacetime flying hour factor and then summing across all aircraft. Manpower requirements are then determined by dividing the total NEC workload by the 60 hour availability factor.

Table A-4

AVIONICS NEC HOURS BY SHOP

			Peace		War	
			Hours	Men	Hours	Men
COMM/NAV						
NEC	AT	6604	101.5		173.1	3
		6605	34.2		60.4	1
		6606	54.4		91.5	2
		6607	10.2	32	18.5	1
		6608	9.1		15.7	
		6609	66.6		134.0	3
		6611	113.2		197.9	4
		6612	53.2		92.8	2
		6613	.5	0	.9	0
		6617	35.2	2	57.6	1
		remaining	84.6	1*	160.3	1*
TOTAL			563.1	35	1002.7	18
ELEC/INST						
NEC	AE	7105	13.5	3	19.5	1
		7109	.8	0	1.2	0
		7133	14.5	1	24.9	1
		7136	.1	0	.2	0
		7144	15.1	(dual to 7105)	21.1	1
		7171	22.0	2	35.6	1
		7175	4.4	1	16.0	1
		remaining	397.3	3	712.6	9
TOTAL			467.7	10	831.1	14
FIRE CONTROL						
NEC	AQ	7921	34.5	2	56.0	1
		7925	0	0	.1	0
		7975	97.6	2	158.3	3
		7976	24.0	2	38.9	1
		$$$$	259.8	12	555.8	10
		****	.1	0	.1	0
		remaining	112.7	0	238.5	2
TOTAL			528.7	18	1047.7	17

Table A-4 (cont.)

	Peace Hours	Peace Men	War Hours	War Men
RADAR/ECM				
NEC AT 6616	39.2	1	60.4	1
6639	64.5	5	121.3	2
6641	44.9	6	76.5	4
6643	68.2		133.8	
6647	172.2	2	246.2	4
6666	43.3	1	61.9	1
6603	12.3	2	20.0	1
remaining	162.8	11*	357.6	15*
TOTAL	607.4	28	1077.7	28
SACE/INS				
NEC AE 7112	24.3	1	44.2	1
7116	162.3	2	262.9	5
7128	46.6	2	75.5	2
7132	22.8	3	39.5	1
7149	92.4	4	269.5	5
AQ 7953	40.6	1	73.5	2
7954	10.2	1	18.4	1
7963	36.5	1	52.2	1
7964	47.5	2	85.0	2
remaining	239.0	4*	480.2	7*
TOTAL	722.2	21	1400.9	27
ASW				
NEC AX 6522	1.2		1.6	
6526	2.1		3.7	
6527	7.1	4	10.0	3
6529	1.5		2.1	
6564	.5		.7	
remaining	29.3	1*	99.1	1*
TOTAL	41.7	5	117.2	4

*Includes ACM-02 billets that have no corresponding workload.

DRMS ANALYSIS WITH NEW WORKLOADS

One factor that contributed to the DRMS recommendation to consolidate repair actions was the very low NEC workloads resulting from the ACM-02 model. Those workloads suggested low personnel utilization and, therefore, the potential for significant manpower savings due to the economies of scale of a consolidated environment. Since the DRMS, the ACM-02 model has been updated, resulting in a 70 percent increase in workload. Personnel utilization has therefore increased, reducing the potential manpower savings due to consolidation.

Other changes have occurred since the DRMS that affect the manpower analysis. The number and type of personnel required has been changed by ACM-02. The current statement of requirements is significantly smaller than the former level of authorizations primarily because of the dual-coding billets. Dual coding also increases personnel utilization. Another change since the DRMS is the question of the proper measure of workload--the ACM-02 values or an escalated figure.

Using current and escalated ACM-02 workloads and billet requirements, a "DRMS type" of analysis was performed to roughly estimate the potential manpower savings due to consolidaing repair actions. The results of this analysis are shown in Table A-5. The assumptions and steps in the analysis are:

1. Consider an NEC billet with a workload of 10 or fewer hours per week as a candidate for transfer to shore.
2. Multiply the workload for each billet by six to estimate the total work per fleet of six carriers that would be transferred to a shore AIMD.

Table A-5

DRMS ANALYSIS WITH NEW WORKLOADS

			Peacetime Workload				Wartime Workloads			
			Per CV		Total NAS		Per CV		Total NAS	
Shop	Aircraft	NEC	Hours(1)	Men(1)	Hours(2)	Men(3)	Hours(1)	Men(1)	Hours(2)	Men(3)
	A-6E/									
COMM/NAV	KA-6D	AT6608	4.9	1	29.4	1	9.6	1	57.6	2
		AT6609	3.7	1	22.2	1	6.8	1	40.8	2
	A-7E	AT6605	6.4	2	38.4	2	10.4	2	62.4	2
	E-2C	AT6605	1.0	1	6.0	1	1.5	1	9.0	1
		AT6606	4.7	1	28.2	1	7.2	1	43.2	2
		AT6609/6612	8.4	1	50.4	2	*	*	*	*
	EA-6B	AT6605	3.1	1	18.6	1	4.4	1	26.4	1
	F-14A	AT6609	18.5	2	111.0	4	*	*	*	*
		AT6605/6612	9.1	2	54.6	2	19.4	2	116.4	4
		AT6607/6611	17.0	2	102.0	4	*	*	*	*
	S-3A	AT6607/6611	5.9	1	35.4	2	*	*	*	*
	SH-3H	AT6605/6608	7.2	1	43.2	2	10.0	1	60.0	2
		AT6609/6612	7.1	1	42.6	2	9.8	1	58.8	2
RAD/ECM	A-7E	AT6603	12.3	2	73.8	3	20.0	2	120.0	4
SACE/INS	E-2C	AE7132	3.9	1	23.4	1	6.0	1	36.0	2
	EA-6B	AQ7964	5.4	1	32.4	2	7.7	1	46.2	2
		AE7132	4.1	1	24.6	1	5.9	1	35.4	2
ASW	S-3A	AX6526	0.4	1	2.4	1	1.3	1	7.8	1
	SH-3H	AX6526	1.7	1	10.2	1	2.4	1	14.4	1
		AX6564/6522	1.7	1	10.2	1	2.5	1	15.0	1
		TOTAL		25 x 6	vs	35		19 x 6	vs	31
				150	vs	35		114	vs	31

(1) From Table A-3.
(2) 6 times hours per CV
(3) NAS hours ÷ 31.9
* NEC workload greater than 10 hours per week.

3. Divide the NAS workload by 31.9 hours per week to estimate the billets required at the NAS AIMD.

4. Compare the total billets on the 6 carriers to the billets at the NAS to estimate manpower savings.

The factors that have increased personnel utilization have reduced the potential manpower savings due to consolidation to 115 billets per fleet or less than 20 per carrier. Using wartime workloads, the savings are further reduced to 83 billets per fleet. Approximately 25 percent of these savings could be gained by combining two 12-aircraft squadrons into single 25-plane units (for the A-7 and F-14).

AIMD TEAM OPTION FOR THE ATLANTIC AND PACIFIC FLEETS

Chapter III of the Note discusses an alternative to the current practice of assigning I-level component repair personnel to the operational squadrons. This option would place the management of all Intermediate Maintenance billets under the AIMDs. One method would be to determine the component repair billets for each carrier on the basis of the total NEC workloads across all aircraft supported by the AIMD. These billets would then be divided into teams that would be sent TAD to the various home NASs when the aircraft transitioned from the carrier to the shore bases.

Tables A-6 and A-7 show one possible composition of such teams for the Atlantic and Pacific fleets. The tables show, for each home NAS, the workloads and team billets by specific NECs. The workloads are the peacetime hours from the ACM-02 model (Table A-1) and the billets are those determined in the exercise outlined in Table A-4.

Table A-6

AIMD TEAM OPTION FOR ATLANTIC FLEET

	Oceana		Jacksonville		Norfolk		Cecil		Whidbey	
Shop/NEC	Hrs.	Men	Hrs.	Men	Hrs.	Men	Hrs.	Men	Hrs.	Men
COMM/NAV										
AT6604	63.3	2					1.2	0	37.0	1
AT6605	19.9	1	3.5	0	1.0	0	6.7	0	3.1	0
AT6606	32.3	1	3.3	0	4.7	0			14.0	1
AT6607/6608	8.1	0	3.7	0	.3	0	5.9	1	1.4	0
AT6609	22.2	1	4.3	0	3.6	1	34.3	1	2.1	0
AT6611	20.6	1	10.9	1	11.0	0	58.4	2	12.3	0
AT6612	7.6	1	2.7	0	4.3	0	37.2	1	.7	0
AT6617							35.6	1		
AT6633					0*	1				
any AT	37.8	0	6.7	0	10.4	0	22.6	0	8.3	0
Shop Total	211.8	7	35.1	1	35.3	2	201.9	6	78.9	2
ELEC/INST										
AE7105			1.0	0	2.3	0			10.2	1
AE7133	4.0	0					10.6	1		
AE7144	.1	0	14.9	1						
AE7171							22.0	1		
AE7175							4.4	1		
any AE	187.7	6	47.4	1	8.4	0	121.8	2	33.0	0
Shop Total	191.8	6	63.3	2	10.7	0	158.8	5	43.2	1
FIRE CTL										
AQ7921	.1	0					34.5	1		
AQ7975							96.7	3		
AQ7976							24.0	1		
AQ$$$$	259.5	10					.3	0		
any AQ	107.1	2					4.8	0		
Shop Total	366.7	12					160.3	5		

RADAR/ECM										
AT6603							12.3	1		
AT6616					39.2	1				
AT6639	42.9	1					21.6	1		
AT6641/6643	69.4	2					26.7	1	17.0	1
AT6647									172.2	4
AT6666									43.3	1
any AT	39.9	2			15.4	0	66.7	1	41.0	2
AT6638									0*	1
AT6644									0*	1
AT6648									0*	2
AT6667									0*	1
AT6674/6675									0*	3
AT6671					0*	1				
AT6615							0*	1		
Shop Total	152.2	5			54.6	2	127.3	5	273.5	16
SACE/INS										
AE7112	24.3	1					.1	0		
AE7116	.4	0					162.3	5		
AE7128							46.6	2		
AE7132	14.8	1			3.9	0			4.1	1
AE7149	62.0	2			10.6	1	38.1	2		
AQ7953	40.6	2							.2	0
AQ7954	10.2	1								
AQ7963	7.1	0							36.5	1
AQ7964	42.1	2							5.4	0
any 650	127.1	2			26.2	0	41.5	0	18.1	0
AT6631					0*	1				
AT6651	0*	1								
AT6655	0*	1								
AT6683					0*	1				
Shop Total	328.6	13			40.7	3	288.6	9	64.3	2
ASW										
AX6522/6526			2.9	1						
AX6526							.4	0		
AX6527/6529			8.6	1						
AX6564			.5	1						
any AX			3.4	0			25.9	0		
AT6614							0*	1		
Shop Total			15.4	3			26.3	1		
MOD REP	258.3	9	2.9	0	16.0	1	84.4	3	47.5	2

TOTAL	-	63	-	6	-	11	-	44	-	23

*Billet with no ACM-02 workload.

Table A-7

AIMD TEAM OPTION FOR PACIFIC FLEET

	Miramar		Lemoore		North Island		Whidbey	
Shop/NEC	Hrs.	Men	Hrs.	Men	Hrs.	Men	Hrs.	Men
COMM/NAV								
AT6604			1.2	0			100.3	3
AT6605	4.6	0	6.4	0	3.8	0	19.4	1
AT6606	4.7	0			3.3	0	46.3	2
AT6607/6608	.3	0	5.0	0	4.6	0	9.5	1
AT6609	22.1	1	25.7	1	12.9	1	5.8	0
AT6611	27.9	1	53.3	2	16.0	1	16.0	0
AT6612	9.7	1	35.0	1	4.9	0	2.9	0
AT6607			35.6	1				
AT6633	0*	1						
any AT	33.0	0	16.6	0	12.7	0	23.5	0
Shop Total	102.3	4	178.8	5	58.2	2	223.7	7
ELEC/INST								
AE7105	2.3	0			1.0	0	10.2	1
AE7133			10.5	1	.1	0	4.0	0
AE7144	.1	0			14.9	1		
AE7171			22.0	1				
AE7175					4.4	1		
any AE	62.2	2	108.3	2	60.9	1	166.9	4
Shop Total	64.6	2	140.8	4	81.3	3	181.1	5
FIRE CTL								
AQ7921	.1	0	34.5	1				
AQ7975			96.7	3				
AQ7976			24.0	1				
AQ$$$$	259.5	10	.3	0				
any AQ	107.1	2	4.8	0				
Shop Total	366.7	12	160.3	5				

RADAR/ECM								
AT6603			12.3	1				
AT6616	39.2	1						
AT6639	24.5	1	21.6	1			18.4	0
AT6641/6643			26.7	1			35.4	1
AT6643	51.0	2						
AT6647							172.2	4
AT6666							43.3	1
any AT	44.1	1	24.7	0	42.0	1	52.0	3
AT6638							0*	1
AT6644							0*	1
AT6648							0*	2
AT6667							0*	1
AT6674/6675							0*	3
AT6671	0*	1						
AT6615					0*	1		
Shop Total	158.8	6	85.3	3	42.0	2	321.3	17
SACE/INS								
AE7112			.1	0			24.3	1
AE7116			162.3	5			.4	0
AE7128			46.6	2				
AE7132	3.9	0					18.9	1
AE7149	54.5	2	.2	0	37.9	2	18.1	1
AQ7953							40.8	2
AQ7954							10.2	1
AQ7963							43.6	1
AQ7964							47.5	2
any 650	79.9	2	6.1	0	35.4	0	91.5	1
AT6631	0*	1						
AT6651							0*	1
AT6655							0*	1
AT6683	0*	1						
Shop Total	138.3	6	215.3	7	73.3	2	295.3	12
VAST	399.1	14	0*	2	219.0	8		
ASW								
AX6522/6526					3.3	1		
AX6527/6529					8.6	1		
AX6564					.5	1		
any AX					29.3	0		
AT6614					0*	1		
Shop Total					41.7	4		

MOD REP	186.8	6	22.1	1	65.2	3	135.0	5
TOTAL	-	50	-	27	-	24	-	46

*Billet with no ACM-02 workload.

The economies gained from manning on total workload cause some shortfalls when spreading the resulting billets back to the NAS AIMDs. These "uncovered" hours are typically very small and exist primarily in the COMM/NAV work center. Although a few extra billets may be required at some NASs, it is quite possible that the excess workload can be covered by the NAS permanent party or OPDET. Furthermore, team composition could vary from CV to CV. For example, one CV team may have one skill represented but be short in a second NEC. The opposite match could occur with the teams from a second carrier, thereby allowing one CV team to cover shortfalls in another CV team.

To determine an optimal composition of CV teams, the interaction between carriers and the capacity of the NASs to absorb excess work has to be considered. The number of billets under an AIMD wartime manning approach is practically identical to the output of the ACM-02 model (147 vs. 148). Therefore, the size of the teams sent TAD from CVs to NASs would be very similar to the total number of billets that ACM-02 would send TAD from the operational squadrons.

Appendix B

WORKLOAD AND COST ESTIMATION METHODOLOGIES

The estimates of workload and cost reported here were developed from component-specific data contained in the CABAL data base [Ref. 1]. Most of these estimates used the "expected values" of parameters to compute workloads, pipeline quantities, and costs. The stockage costs of moving some VAST repair ashore, however, were based on evaluation of the stock required to provide a 90 percent probability that a component would be available when needed. The methodologies used to derive these estimates are described in this Appendix.

PIPELINE AND WORKLOAD ESTIMATES

Expected daily demands for a component are assumed to be a linear function of aircraft flying hours and the component's demand rate. This defines the Daily Demand Rate (DDR):

$$DDR = (\text{Flying Hours/Day}) \times (\text{Demands/Flying Hour})$$

It is assumed that all shipboard reparable items are tested after removal. Testing leads either to successful completion of a repair action or to a determination that the repair is Beyond Capability of Maintenance (BCM). BCM actions flow through the off-ship repair pipeline.

The requirement for test time is assumed to be a function of component failures and the Elapsed Maintenance Time (EMT) required to effect a repair.[1] Thus the total daily demand for test time (TTD) is the sum over the components, j, of test time requirements:

$$TTD = \sum_{j} DDR \times EMT$$

Similarly, Maintenance Manhour Demand (MMD) is a function of the number of failures and the hours required to test (and if possible repair) an item:

$$MMD = \sum_{j} DDR \times [(\text{Test Hours}) + (1 - BCM)\ (\text{Repair Hours})]$$

The expected number of assets of a particular type in a pipeline or pipeline segment, i, is also a function of the demand rates:

$$P_i = DDR \times (\text{fraction entering } i) \times (\text{Time spent in } i)$$

For example, to compute the expected number of components in the AWP pipeline at an AIMD:

[1] As noted in the body of the report, EMT was used as a proxy for test time.

$$P_{AWP} = \sum_{j} DDR \times (\text{Fraction repaired in the AIMD})$$
$$\times\ (\text{Average AWP time per component repaired in the AIMD})$$

$$= \sum_{j} DDR \times (1 - BCM) \times AWP\ Days$$

The cost of the pipeline segment ($\$P_i$) is simply the expected number of components in the pipeline times the unit price.

$$\$P_i = P_i \times Price$$

The total cost of this segment (TCP_i) is then:

$$TCP_i = \sum_{j} \$P_i$$

STOCKAGE COSTS

The rough cut at pipeline costs described above does not provide a realistic estimate of the stockage cost of a shore repair alternative. Stockage requirements calculations recognize the stochastic properties of the component demand process and attempt to provide a specified level of confidence that replacement components will be available when required. Further, stock must be supplied in integer quantities, while the expected value of pipeline requirements are not subject to this constraint.

Assuming that the observed historical demand rate represents the mean of a Poisson distribution, the stock required under the two alternative structures can be calculated by evaluating the function

$$\sum_{s=0}^{k-1} \frac{e^{-\lambda T} \lambda T^{K}}{k!}$$

until K, the stockage quantity, is such that the expression exceeds the target "fill rate." Here λT is

$$\sum_{i} P_{i} ,$$

or the expected number of components in all of the pipelines. Stockage cost is then

$$\sum_{j} K \times (\text{Price}).$$

<u>VAST COMPONENTS SELECTED FOR SHORE REPAIR</u>

The difference between stockage costs for the shipboard and shore repair alternatives reported in the basic document were based on application of this procedure for components having the lowest "marginal value of test time" (MVTT). The MVTT was computed by dividing the expected difference in pipeline costs by expected daily test demands. In other words, the components selected were those for which the costs of freeing up an hour of VAST capacity were the lowest; components were added to this list until the capacity shortfall was alleviated.

This does not consider the costs of transporting additional components to and from the carrier. The volume of shipments involved, however, is insignificant in relation to the total existing movement requirement.

REFERENCES

1. Embry, L., and P. Dey, Carrier Based Air Logistics Study--Data Sources and Issues, The Rand Corporation, N-1791-NAVY, forthcoming.

2. Hillestad, R. J., Dyna-METRIC, Dynamic Multi-Echelon Technique for Recoverable Item Control, The Rand Corporation, R-2785-AF, forthcoming.

3. Hillestad, R. J., and L. Embry, Carrier Based Air Logistics Study--Supply and Transportation Analysis, The Rand Corporation, N-1785-NAVY, forthcoming.

4. Hillestad, R. J., and M. J. Carrillo, Models and Techniques for Recoverable Item Stockage When Demand and the Repair Process are Nonstationary--Part I: Performance Measurement, The Rand Corporation, N-1482-AF, May 1980.

5. Lippiatt, T., R. Hillestad, L. Embry, and J. Schank, Carrier Based Air Logistics Study: Integrated Summary, The Rand Corporation, R-2853-NAVY, forthcoming.

6. Monger, A. J., "Revised Study Plan for AIMD Component Repair Migration," Minutes of the CABAL Advisory Committee Meeting, OP-05, U.S. Navy, 29 February 1980.

7. Naval Aviation Logistics Command Management Information System--Functional Description, NAVAIRSYSCOM Document No. 41L001, Fd-01, 16 May 1977.

8. Perform Intermediate Aircraft Maintenance: ACM-02, Navy Manpower and Material Analysis Center, Atlantic, Norfolk, VA, 30 March 1979.

9. Rice, D. B., Defense Resource Management Study: Case Studies of Logistics Support Alternatives, U.S. Government Printing Office, Washington, D.C., February 1979.

DATE
FILMED

5-8